# AIR QUALITY MANUAL

# MOTOR VEHICLE EMISSION FACTORS FOR ESTIMATES OF HIGHWAY IMPACT ON AIR QUALITY

72-10


**STATE OF CALIFORNIA**

**BUSINESS AND TRANSPORTATION AGENCY**

**DEPARTMENT OF PUBLIC WORKS**

**DIVISION OF HIGHWAYS**

**MATERIALS AND RESEARCH DEPARTMENT**


**AIR QUALITY MANUAL**


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State of California
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# MOTOR VEHICLE EMISSION FACTORS FOR ESTIMATES OF HIGHWAY IMPACT ON AIR QUALITY

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72-10

## FOREWORD

A number of studies must be completed prior to the writing of an Environmental Impact Statement for a highway project. One of these studies is concerned with the gathering of field data, analysis of such data, and writing an air quality report.

The California Division of Highways has embarked on a program of equipping and training district personnel to prepare air quality reports. This requires a two-week training course and the preparation of air quality manuals to be used as guides in the gathering of field data, analysis of results, and writing the report.

This manual is the second in a series of six manuals, the titles of which follow:

1. Meteorology and its Influence on the Dispersion of Pollutants from Highway Line Sources.

2. Motor Vehicle Emission Factors for Estimates of Highway Impact on Air Quality.

3. Traffic Information Requirements for Estimates of Highway Impact on Air Quality.

4. Mathematical Approach to Estimating Highway Impact on Air Quality.

5. Analysis of Ambient Air Quality for Highway Environmental Projects.

6. A Method for Analyzing and Reporting Highway Impact on Air Quality.

The material presented in these manuals is subject to change as further research provides information. The following items are not discussed or, if presented, are subject to care in the interpretation of results.

1. There are no accepted emission factors for oxides of nitrogen relating emissions to speed.

2. There are no statistically validated photochemical models for different meteorological conditions which will permit calculations of oxidant formed downwind from a line source.

3. Further research is required to fully validate model calculations when winds blow parallel to the line source.

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This work was accomplished in cooperation with the United States Department of Transportation, Federal Highway Administration. The opinions, findings, and conclusions expressed in this publication are those of the California Division of Highways and not necessarily those of the Federal Highway Administration.

# TABLE OF CONTENTS

TABLE OF CONTENTS (con't.)

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF FIGURES (Con't)

## INTRODUCTION

This manual summarizes the work done by the California Division of Highways, Materials and Research Department, in preparing emission factors for motor vehicles based on California and Federal test standards. The first part of this summary covers emission factors which are most representative of vehicles using freeways, and the second part presents the emission factors which are most representative of vehicles on city streets. The third part discusses the applications and limitations of the emission factors that are developed. These emission factors take into account the deterioration factors, model year, mileage travelled per year and average route speed. The basic relationship between emissions and average route speed was derived by Rose[1] in earlier research.

This manual is based primarily on the work of Harrison W. Sigworth, Jr. [2], Environmental Protection Agency (EPA), Research Triangle Park, North Carolina. The main differences between the approaches by Sigworth and the California Division of Highways are that this manual includes the vehicle mix, annual mileage travelled per model year, average route speed and emission factors based on conditions that exist in California. It is the concensus of the agencies involved that the California Air Resources Board test procedure is more realistic for freeway use while the emission factors based on the 1972 Federal test procedures are more representative of city type emission rates. Both of these procedures were used in developing the emission factors.

In order to determine the impact of highway on the local environment, a comparison must be made of vehicular emissions from highways and city streets. This comparison should indicate the increase or decrease of pollutant load as a function of traffic volume and associated average route speed. The emission factor curves developed in this manual can be used to determine separate emission factors for carbon monoxide and hydrocarbons on highways and city streets as a function of average route speed. On this basis, a mesoscale analysis of these pollutants can be made. In addition, these carbon monoxide emission factors are suitable for use as input into a highway line source dispersion model to estimate pollution concentrations on and within the highway corridor [3].

While carbon monoxide emission factors may be used for both corridor and mesoscale analysis, hydrocarbon emission factors are only applied on a mesoscale basis since hydrocarbons are not considered a localized health hazard in the concentrations produced by vehicular traffic.

The developed emission factors are based on the best data obtainable. At present no statistically significant data are available to establish a relationship between oxides of nitrogen emissions and average route speed. As a consequence, no current realistic analysis of $NO_x$ concentrations can be made on either a corridor or mesoscale basis. When more data become available for $NO_x$ or any other pollutant, these factors will be updated or developed to reflect such changes.

## EMISSION FACTORS FOR VEHICLES USING FREEWAYS

### Emission Standards: California Air Resources Board

A summary of the emission standards for light duty vehicles (LDV) and heavy duty vehicles (HDV) including past and present model years is presented in Table 1. These standards are for carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen ($NO_x$). Also included in the table are the crankcase and evaporative losses of HC for both light and heavy duty vehicles. The emission standards in this table were established by the California Air Resources Board (ARB).

These standards are based on the ARB hot test procedure using the 7-mode test cycle outlined below:

| Sequence No. | Mode MPH | Acceleration MPH in Secs. | Elapsed Time Seconds | Cumulative Time Seconds |
|---|---|---|---|---|
| 1 | Idle | - | 20 | 20 |
| 2 | 0 to 30 | 2.2 | 14 | 34 |
| 3 | 30 | - | 15 | 49 |
| 4 | 30 to 15 | -1.4 | 11 | 60 |
| 5 | 15 | - | 15 | 75 |
| 6 | 15 to 50 | 1.2 | 29 | 104 |
| 7 | 50 to 0 | -1.5 | 33 | 137 |

The total distance traveled is 0.86 miles and the average speed of this 7-mode cycle is 22.6 mph.

The 7-mode cycle is based on typical driving modes on Los Angeles freeways during peak traffic hours. It should be stressed at this time that emission factors for a cruise-type operating mode would be less than those indicated by the ARB test procedure, especially for the year 1974 and earlier model cars. However, more research will be required to indicate the amount of reduction. This is discussed in more detail in a later section of this manual.

### Deterioration Factors for Controlled Vehicles Using Freeways

The deterioration of exhaust emission controls for light and heavy duty vehicles has been estimated by regression equations as described by Sigworth [2]. The deterioration equations are described below for each pollutant for the year indicated:

Carbon Monoxide CO

1966, 1967 LDV CO:

$$D.F. = 0.950 + 0.0150(MI) - 0.00036(MI)^2 + 0.0000032(MI)^3 + 0.00375(Q) \quad (1)$$

1968 & later LDV CO:

$$D.F. = 0.930 + 0.02(MI) - 0.00043(MI)^2 + 0.0000037(MI)^3 + 0.00456(Q) \quad (2)$$

1973 & later HDV CO:

Same as equation (2).

Hydrocarbons HC

1966, 1967 LDV HC:

$$D.F. = 0.937 + 0.0186(MI) - 0.00042(MI)^2 + 0.00000368(MI)^3 + 0.00412(Q) \quad (3)$$

1968 & later LDV HC:

$$D.F. = 0.951 + 0.0146(MI) - 0.00034(MI)^2 + 0.0000031(MI)^3 + 0.00345(Q) \quad (4)$$

1970 & later HDV HC:

Same as equation (4).

In all of the above equations the respective parameters are as follows:

D.F. = deterioration factor

MI = vehicle mileage up to 50,000 miles in thousands of miles

Q = vehicle mileage over 50,000 miles (total miles - MI) in thousands of miles.

These deterioration equations were derived by Sigworth, using ARB data for California LDV with less than 50,000 miles. Deterioration factors for mileage greater than 50,000 miles were estimated using straight line interpolations from the 50,000 mile deterioration factors and the slope at that point. The maximum mileage used in the deteorioration equations is 109,800 miles. The deterioration factor for mileage beyond this is assumed equal to the 109,800 mile value. Because of lack of quantitative data for HDV, the deterioration equations for LDV were assumed applicable to HDV as indicated in the equations except that deterioration factors beyond 109,800 miles are computed from the equations directly. Values for these deterioration factors for LDV and HDV at estimated cumulative year-end mileages are given in Tables 2 and 3, respectively. Estimates for the year-end mileages are shown in Tables 4 and 5.

## Estimated HDV Travel Per Year

In order to obtain a composite emission factor for the total vehicles using a highway (HDV plus LDV) for a given time period the percentage of LDV and HDV must be known.

A summary of the light duty vehicle mix for a given age of vehicle versus annual miles traveled and percentage of miles traveled is given in Table 4. These data were obtained from the California Air Resources Board [4] as being the representative vehicle mix that exists in California for light duty vehicles.

In order to take into account the percent contribution of both LDV and HDV traveled on a highway it is necessary to consider annual miles traveled by HDV to be used in the deterioration equations. The best available information on the estimated average yearly mileage of HDV was obtained from the California Trucking Association in San Francisco. This estimate from the California Trucking Association was 14,000 miles per year for HDV which includes long and short haul trips.

In this report an average mileage of 14,000 miles per year was assumed for all HDV. A table of vehicle travel vs. age for HDV is given in Table 5.

## Overall Emission Factors for Vehicles Using Freeways

A summary of the emission factors (1972-2000) for LDV and HDV using freeways, based on ARB standards is given in Table 6 for a 5% HDV mix. The values in the table were computed by multiplying the emission factor (Table 1) times the appropriate deterioration factor (Table 2 and 3), and then weighting according to the vehicle age vs. travel data obtained from Tables 4 and 5. This procedure was followed for both LDV and HDV and the resulting emission factors for each were then weighted according to the percentage of LDV and HDV using the highway to give an overall average emission rate. A sample calculation for the year 1972 is presented in Appendix A. These emission rates, when multiplied by the total vehicle miles traveled on freeways for a given time period, will give the total mass of CO and HC emitted by LDV and HDV. This includes the vehicle model year mix during that time period and assumes an average route speed of 22.6 mph. There are certain highways that may have a larger percentage of HDV than 5% as indicated in Table 6. In order to be able to estimate the emission factors for these conditions, HDV mixes of 10%, 15%, and 20% are presented in Tables 7 through 9. If the percentage of HDV using the highway is between these values a straight line interpolation can be used to estimate the emission factor.

## Emission Factors vs. Average Route Speeds for Vehicles Using Freeways

It is known that the amount of emissions of carbon monoxide and hydrocarbons* from the exhaust of an uncontrolled vehicle will depend mainly on the average route speed and engine operating mode[1] (idle, acceleration, deceleration and cruise). This relationship was studied by Rose and was developed using 1963 and earlier model year vehicles with no exhaust emission controls. The relationship is shown in Figures 1 and 10. At present no statistically significant relationship between oxides of nitrogen and average route speed has been established, by ARB or EPA so development of such curves is dependent upon further research in this area. From the limited data available, however, it appears that $NO_x$ emissions increase with higher average route speeds[6].

Sigworth of the Environmental Protection Agency indicates that Rose's work (shape of curves) is probably valid for vehicles without exhaust emission controls but is probably less valid though still roughly applicable for pre-1975 vehicles with exhaust emission controls. For these latter vehicles the emission factors would be reduced, when compared to the uncontrolled curve as derived by Rose, but probably would have the same

*Automotive hydrocarbon emissions are pertinent to air quality analyses primarily because of their role in oxidant formation by photochemical reactions. The ARB has no ambient air quality standard for hydrocarbons because it is felt that their standard for photochemical oxidants automatically limits ambient hydrocarbon concentrations. The EPA has set an air quality standard for hydrocarbons, not for health purposes, but as extra insurance that the oxidant standards are met.

slope. Sigworth points out because of the radically different emission characteristics of 1975 and later vehicles, that he expects the curves would have little applicability to them.

Information received from the Air Resources Board [4] indicates that, with today standards, the 1975 and later vehicle will be essentially "pollution free." The emissions from these vehicles should be independent of route speed. This means that some time after all the pre-1975 model vehicles are phased out or non-operative the emission levels from vehicles will remain constant except for some deterioration in the devices themselves.

In order to relate the average route speed vs. emission factors for CO and HC with the yearly vehicle mix subsequent to 1974, the following assumptions were made:

1) For highway travel, emission estimates, it is valid to use the ARB 7-mode test cycle procedure. It was further assumed that Rose's curve was valid for the ARB test procedure.

2) The characteristic shapes and slopes of Rose's curves are valid up to the pre-1975 model year.

3) In 1986 the vehicle mix on freeways will be entirely 1975 models or later (essentially "pollution free") and the emission factor will be relatively independent of route speed. (This estimate was obtained from data received from ARB and is illustrated in Tables 6 through 9 with the emission factors remaining constant from 1986 and later.)

4) The use of the emission factors from Table 6 for the years 1972 through 1986 with an average route speed of 22.6 mph is valid.

5) It is sufficiently accurate to extrapolate the slopes of the emission factor vs. average route speed curves for post 1975 highway vehicles from the known ARB emission factors and from the boundary curves for 1974 and 1986.

The carbon monoxide and hydrocarbon emission factors for a 5% HDV mix versus average route speed of vehicles using freeways are shown in Figures 2 and 11 respectively. These curves take into consideration the vehicle mix per year indicated, the emission standards, and the deterioration factors. The two series of curves, for an indicated year, represent the amount of carbon monoxide or hydrocarbons, with respect to the average route speed, that is emitted from vehicles using freeways. These curves also illustrate that an increase in the average route speed of vehicles using freeways will reduce the load of these two pollutants. The curves also show that, as the pre-1975 models are phased out, the emission factors become more independent of route speed. Similar curves for 10%, 15% and 20% HDV mixes are given in Figures 3-5 for carbon monoxide and Figures 12-14 for hydrocarbons. If the HDV mix is between these values, a straight line interpolation can be used to estimate the emission factors.

## EMISSION FACTORS FOR VEHICLES USING CITY STREETS

This section discusses the 1972 Federal test procedure and emission standards. The computational methodology is similar to that of Sigworth[2]. The only exception is that the vehicle mix and percentage of miles traveled annually by LDV and HDV are based on conditions that exist in California as was previously discussed.

### Emission Standards: 1972 Federal Test Procedures

A summary of the past and present Federal Emission standards for LVD and HDV are presented in Table 10.

These standards are based on the 1972 Federal test procedure[5] using a driving cycle representative of the "LA-4" route near downtown Los Angeles during peak traffic periods. The average driving cycle speed is 19.6 mph and its length is 7.5 miles. Exhaust is collected by constant volume sampling equipment during this driving cycle, after a 12 hour cold soak prior to turning on the vehicle's ignition key. The collected exhaust is then analyzed for CO, $NO_x$, and HC content and converted to mass emission. This Federal test procedure using a cold start is representative of the driving mode of vehicles using city streets.

### Deterioration Factors for Controlled Vehicles Using City Streets

The deterioration factors and assumptions for the Federal test procedure for LDV and HVD are the same as used for freeway emission factors. (See Tables 2 and 3.)

### Estimated HDV Travel Per Year

The estimated HDV travel per year assumptions used with the Federal test procedure are the same as those used for the freeway emission factors.

### Overall Emission Factors for Vehicles Using City Streets

A summary of the emission factors (1972-2000) for vehicles using city streets, based on the 1972 Federal test procedure, is given in Table 11 for a 5% HDV mix. The values in the table were computed similarly to those in Part 1 except that Federal standards, as given in Table 10, were used for LDV and HDV emission factors. A sample calculation for the year 1972 is presented in Appendix B. These emission factors, when multiplied by the total vehicle miles traveled on city streets for a given time period, will give the total mass concentration of CO and HC emitted by LDV and HDV. This includes the vehicle model year mix during that time period and assumes an average route speed of 19.6 mph. Other emission factors are given in Tables 12 through 14, inclusive, for HDV mixes of 10%, 15%, and 20%. If the percentage of HDV using the highway is between these values, a straightline interpolation can be used to estimate the emission factors.

## Emission Factors vs. Average Route Speed for Vehicles Using City Streets

This section will discuss the development of emission factor curves for carbon monoxide and hydrocarbons vs. average route speed of vehicles using city streets. The analysis is very similar to the emission factors vs. average route speed of vehicles using freeways. The following assumptions were made for this analysis for a 5%, 10%, 15%, and 20% HDV mix:

1) The characteristic shapes and slopes of Rose's curves are valid up to the pre-1975 model year.

2) The Federal test procedure is valid for estimating vehicle emissions in city street trips.

3) In 1986 the vehicle mix on city streets will be entirely 1975 models or later.

4) The emission factors for a 5%, 10%, 15%, and 20% HDV mix for the years 1972 through 1986 for an average route speed of 19.6 mph, obtained from Tables 11 through 14, are valid.

5) It is sufficiently accurate to extrapolate the slopes of the emission factor vs. average route speed curves for post 1975 vehicles from the known EPA emission factors and from the boundary curves for 1974 and 1986.

The carbon monoxide and hydrocarbon emission factors for various HDV mixes vs. average route speed of vehicles using city streets are illustrated in Figures 6-9 and 15-18 respectively. These curves take into consideration the vehicle mix per year indicated, the emission standards, and the deterioration factors. These curves, for an indicated year, represent the amount of carbon monoxide or hydrocarbons with respect to average route speed that is emitted from vehicles using city streets. These curves also illustrate that if the average route speed on city streets is increased it will reduce the pollutant load of carbon monoxide and hydrocarbons. If the HDV mix is between these values a straight line interpolation can be used to estimate the emission factors.

# APPLICATIONS AND LIMITATIONS

## Application of Emission Factors

The carbon monoxide emission factors vs. average route speed presented in Figures 2 through 5 will be used as input into a highway line source dispersion model [3] to estimate the pollution levels on and within the highway corridor. Hydrocarbon emission factors will not enter into a corridor analysis because the hydrocarbon concentrations involved are not considered a health hazard by either the California Air Resources Board or the Environmental Protection Agency.

In order to estimate the mesoscale pollution levels in the immediate air basin, a comparison must be made of CO and HC emission factors from freeways and city streets. This comparison will indicate the increase or reduction of pollutant load as a function of traffic volume on freeways and city streets and changes in their associated route speeds. The curves in Figures 2-9 and Figures 11-18, depending on the HDV mix, will determine the CO and HC emission factors as a function of average route speed. A final determination of the pollutant load can then be made, based on the increased freeway traffic and the reduction of traffic on city streets, together with the associated average route speeds.

## Limitation of Results

The emission factors and curves presented in this report are developed from two entirely different test procedures and types of equipment, that is, the ARB hot test and 1972 Federal test procedures. These differences in procedures influence the emission factors since they are not totally compatible. The relationship between oxides of nitrogen emission factors and average route speed has not been presented in this report due to a lack of quantitative data in this area at the present time. Until further research results become known, the emission factors which are included in this report are considered by the Division of Highways as being the best available. When more data become available, emission factors will be updated or developed to reflect such changes.

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5. Federal Register, Vol 35, No. 136 - Wednesday, July 15, 1970 [45 CFR, Part 85], Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines.

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Table 1

VEHICLE EMISSION STANDARD - AIR RESOURCES BOARD (ARB)

(All STandards are in GMS./MI.

| | Light Duty Vehicles (LDV) (under 6000 lbs.) | | | | | | Heavy Duty Vehicles (HDV) (over 6000 lbs.) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Exhaust CO | Exhaust $NO_x$ | Exhaust HC | Crank HC | Evap. HC | HC Total | Exhaust CO | Exhaust $NO_x$ | Exhaust HC | Crank HC | Evap. HC | HC Total |
| 1965 | 80 | 4.0 | 11 | 0 | 3.0 | 14 | 165 | 44 | 44 | 5.2 | 3.0 | 52.2 |
| 1966 | 34 | 5.5 | 3.5 | | | 6.5 | 165 | 44 | 44 | 5.2 | | 52.2 |
| 1967 | 34 | 5.5 | 3.5 | | | 6.5 | 165 | 44 | 44 | 5.2 | | 52.2 |
| 1968 | 34 | 5.5 | 3.5 | | | 6.5 | 165 | 44 | 44 | 0 | | 47.0 |
| 1969 | 34 | 5.5 | 3.5 | | 3.0 | 6.5 | 165 | 44 | 44 | | | 47.0 |
| 1970 | 23 | 5.0 | 2.2 | | 0 | 2.2 | 80 | 15.1 | 15.1 | | | 18.1 |
| 1971 | 23 | 4.0 | 2.2 | | | 2.2 | 80 | 15.1 | 15.1 | | | 18.1 |
| 1972 | 23 | 3.0 | 1.5 | | | 1.5 | 80 | 15.1 | 15.1 | | | 18.1 |
| 1973 | 23 | 1.3 | 1.5 | | | 1.5 | 43 | 9.5 | 6.5 | | 3.0 | 9.5 |
| 1974 | 23 | 1.3 | 1.5 | | | 1.5 | 43 | 9.5 | 6.5 | | 0.8 | 7.3 |
| 1975 | 12 | 1.0 | 0.5 | | | 0.5 | 27 | 3.0 | 2.0 | | | 2.8 |
| 1976 | 2.5 | | | | | | | 3.0 | | | | |
| 2000 | 2.5 | 1.0 | 0.5 | 0 | 0 | 0.5 | 27 | 3.0 | 2.0 | 0 | 0.8 | 2.8 |

TABLE 2

EMISSION CONTROL

DETERIORATION FACTOR VALUES FOR LIGHT DUTY VEHICLES (LDV)

| Factor | Deterioration Factor at Miles | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15000 | 28000 | 39000 | 48600 | 57000 | 64000 | 69300 | 74300 | 78700 | 82900 | 86400 |
| CO: 1966 1967 | 1.16 | 1.16 | 1.18 | 1.20 | 1.23 | 1.25 | 1.27 | 1.29 | 1.31 | 1.32 | 1.34 |
| CO: 1968 & later | 1.15 | 1.23 | 1.28 | 1.31 | 1.35 | 1.38 | 1.41 | 1.43 | 1.45 | 1.47 | 1.49 |
| HC: 1966 1967 | 1.13 | 1.21 | 1.24 | 1.27 | 1.31 | 1.34 | 1.36 | 1.38 | 1.40 | 1.42 | 1.43 |
| HC: 1968 & later | 1.10 | 1.16 | 1.19 | 1.21 | 1.24 | 1.27 | 1.29 | 1.30 | 1.32 | 1.33 | 1.35 |

*Note: For CO and HC pre-1966 vehicles deterioration factors are 1.00.

TABLE 3

EMISSION CONTROL

DETERIORATION FACTOR VALUES FOR HEAVY DUTY VEHICLES (HDV)

| Factor | Deterioration Factor at Miles | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 14000 | 28000 | 42000 | 56000 | 70000 | 84000 | 98000 | 112000 | 126000 | 140000 | 154000 |
| CO: 1970 & later | 1.15 | 1.23 | 1.29 | 1.35 | 1.41 | 1.48 | 1.54 | 1.60 | 1.67 | 1.73 | 1.79 |
| HC: 1970 & later | 1.10 | 1.16 | 1.19 | 1.24 | 1.29 | 1.34 | 1.39 | 1.43 | 1.48 | 1.53 | 1.58 |

*Note: For CO and HC pre-1971 vehicle deterioration factors are 1.0

Table 4

Vehicle Travel vs. Age (LDV)

| Age (Yrs) | % of Vehicles | Annual Mileage | % Miles Traveled |
|---|---|---|---|
| 1 | 10.8 | 15,000 | 17.4 |
| 2 | 10.5 | 13,000 | 15.0 |
| 3 | 10.2 | 11,000 | 12.7 |
| 4 | 9.8 | 9,600 | 11.1 |
| 5 | 9.3 | 8,400 | 9.7 |
| 6 | 8.8 | 7,000 | 8.1 |
| 7 | 8.1 | 5,300 | 6.1 |
| 8 | 7.2 | 5,000 | 5.8 |
| 9 | 6.2 | 4,400 | 5.1 |
| 10 | 5.1 | 4,200 | 4.9 |
| > 10 | 13.0 | 3,500 | 4.1 |

Table 5

Vehicle Travel vs. Age (HDV)

| Age (Yrs.) | % Vehicles | Annual Mileage | % Miles Traveled |
|---|---|---|---|
| 1 | 10.8 | 14,000 | 9.09 |
| 2 | 10.5 | 14,000 | |
| 3 | 10.2 | 14,000 | |
| 4 | 9.8 | 14,000 | |
| 5 | 9.3 | 14,000 | |
| 6 | 8.8 | 14,000 | |
| 7 | 8.1 | 14,000 | |
| 8 | 7.2 | 14,000 | |
| 9 | 6.2 | 14,000 | |
| 10 | 5.1 | 14,000 | |
| >10 | 13.0 | 14,000 | 9.09 |

## TABLE 6

### EMISSION FACTORS FOR VEHICLES USING FREEWAYS (ARB) - 5% HDV MIX

| Year | CO | HC |
|---|---|---|
| 1972 | 49.11 | 7.98 |
| 1973 | 45.48 | 7.36 |
| 1974 | 42.22 | 6.32 |
| 1975 | 37.08 | 5.17 |
| 1976 | 30.85 | 4.19 |
| 1977 | 26.35 | 3.44 |
| 1978 | 22.31 | 2.76 |
| 1979 | 18.39 | 2.12 |
| 1980 | 14.93 | 1.56 |
| 1981 | 12.63 | 1.35 |
| 1982 | 10.59 | 1.14 |
| 1983 | 8.65 | 0.97 |
| 1984 | 7.11 | 0.85 |
| 1985 | 5.68 | 0.78 |
| 1986-2000 | 5.12 | 0.78 |

All factors in grams per mile (gm/mi).

see Append. A

TABLE 7

EMISSION FACTORS FOR VEHICLES USING FREEWAYS (ARB) - 10% HDV MIX

| Year | CO | HC |
|---|---|---|
| 1972 | 54.24 | 9.82 |
| 1973 | 50.33 | 9.05 |
| 1974 | 46.79 | 7.87 |
| 1975 | 41.38 | 6.56 |
| 1976 | 34.93 | 5.41 |
| 1977 | 30.14 | 4.48 |
| 1978 | 25.79 | 3.63 |
| 1979 | 21.57 | 2.82 |
| 1980 | 17.80 | 2.09 |
| 1981 | 15.21 | 1.78 |
| 1982 | 12.85 | 1.47 |
| 1983 | 10.56 | 1.20 |
| 1984 | 8.97 | 1.09 |
| 1985 | 7.48 | 0.94 |
| 1986-2000 | 6.95 | 0.94 |

All factors in grams per mile (gm/mi).

TABLE 8

EMISSION FACTORS FOR VEHICLES USING FREEWAYS (ARB) - 15% HDV MIX

| Year | CO | HC |
|---|---|---|
| 1972 | 59.38 | 11.67 |
| 1973 | 55.18 | 10.75 |
| 1974 | 51.35 | 9.42 |
| 1975 | 45.67 | 7.95 |
| 1976 | 39.01 | 6.63 |
| 1977 | 33.93 | 5.52 |
| 1978 | 29.28 | 4.49 |
| 1979 | 24.75 | 3.52 |
| 1980 | 20.67 | 2.62 |
| 1981 | 17.79 | 2.22 |
| 1982 | 15.10 | 1.81 |
| 1983 | 12.47 | 1.43 |
| 1984 | 10.83 | 1.23 |
| 1985 | 9.27 | 1.10 |
| 1986-2000 | 8.77 | 1.10 |

All factors in grams per mile (gm/mi).

TABLE 9

EMISSION FACTORS FOR VEHICLES USING
FREEWAYS (ARB) - 20% HDV MIX

| Year | CO | HC |
|---|---|---|
| 1972 | 64.51 | 13.52 |
| 1973 | 60.03 | 12.72 |
| 1974 | 55.90 | 10.96 |
| 1975 | 49.96 | 9.34 |
| 1976 | 43.06 | 7.86 |
| 1977 | 32.72 | 6.57 |
| 1978 | 32.76 | 5.36 |
| 1979 | 27.94 | 4.22 |
| 1980 | 23.53 | 3.15 |
| 1981 | 20.36 | 2.65 |
| 1982 | 17.36 | 2.14 |
| 1983 | 14.39 | 1.66 |
| 1984 | 12.70 | 1.42 |
| 1985 | 11.07 | 1.25 |
| 1986-2000 | 10.60 | 1.25 |

All factors in grams per mile (gm/mi).

TABLE 10

VEHICLE EMISSION STANDARDS- 1972 FEDERAL TEST PROCEDURES
ALL STANDARDS ARE IN GMS/MI.

| Year | Light Duty Vehicles (LDV) (under 6000 lbs.) | | | | | | Heavy Duty Vehicles (HDV) (over 6000 lbs.) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exhaust CO | Exhaust $NO_x$ | Exhaust HC | Crank HC | Evap. HC | HC Total | Exhaust CO | Exhaust $NO_x$ | Exhaust HC | Crank HC | Evap. HC | HC Total |
| 1965 | 110 | 6.4 | 13.1 | 0 | 3.0 | 16.1 | 129 | 9.5 | 18.7 | 5.2 | 3.0 | 26.9 |
| 1966 | 62 | 7.1 | 5.9 | | 3.0 | 8.9 | 129 | | | | | 26.9 |
| 1967 | 62 | 7.1 | 5.9 | | 3.0 | 8.9 | 129 | | | | | 26.9 |
| 1968 | 50 | 7.1 | 5.6 | | 3.0 | 8.6 | 129 | | | 5.2 | | 26.9 |
| 1969 | 50 | 7.1 | 5.6 | | 3.0 | 8.6 | 129 | | 18.7 | 0 | | 21.7 |
| 1970 | 35 | 5.5 | 3.5 | | 0.49 | 4.0 | 80 | | 15.1 | | | 18.1 |
| 1971 | 35 | 4.4 | 3.5 | | 0.49 | 4.0 | 80 | | 15.1 | | | 18.1 |
| 1972 | 31 | 4.4 | 3.1 | | 0.16 | 3.3 | 53 | | 9.9 | | 3.0 | 12.9 |
| 1973 | 31 | 2.7 | 3.1 | | | 3.3 | 43 | | 7.8 | | 0.8 | 8.6 |
| 1974 | 31 | 1.7 | 3.1 | | | 3.3 | 43 | 9.5 | 7.8 | | | 8.6 |
| 1975 | 4.7 | 1.2 | 0.5 | | | 0.7 | 27 | 3.0 | 2.4 | | | 3.2 |
| 1976 | 4.1 | 0.5 | 0.4 | | | 0.6 | | | | | | |
| 1977 | 4.1 | 0.4 | 0.4 | | | 0.6 | | | | | | |
| 1978 | 4.1 | 0.4 | 0.4 | | | 0.6 | | | | | | |
| 2000 | 4.1 | 0.4 | 0.4 | 0 | 0.16 | 0.6 | 27 | 3.0 | 2.4 | 0 | 0.8 | 3.2 |

TABLE 11

EMISSION FACTORS FOR VEHICLES USING
CITY STREETS (EPA) - 5% HDV MIX

| Year | CO | HC |
|---|---|---|
| 1972 | 67.80 | 10.49 |
| 1973 | 63.39 | 8.72 |
| 1974 | 57.74 | 7.77 |
| 1975 | 48.12 | 6.44 |
| 1976 | 40.21 | 5.27 |
| 1977 | 33.70 | 4.34 |
| 1978 | 27.92 | 3.51 |
| 1979 | 22.89 | 2.80 |
| 1980 | 18.55 | 2.18 |
| 1981 | 15.67 | 1.83 |
| 1982 | 12.90 | 1.49 |
| 1983 | 10.79 | 1.26 |
| 1984 | 8.84 | 1.06 |
| 1985 | 7.14 | 0.87 |
| 1986 | 7.11 | 0.87 |
| 1987-2000 | 7.11 | 0.87 |

All factors in grams per mile (gm/mi).

TABLE 12

EMISSION FACTORS FOR VEHICLES USING CITY STREETS (EPA) - 10% HDV MIX

| Year | CO | HC |
|---|---|---|
| 1972 | 70.43 | 11.20 |
| 1973 | 65.00 | 9.45 |
| 1974 | 60.28 | 8.47 |
| 1975 | 50.80 | 7.11 |
| 1976 | 42.94 | 5.91 |
| 1977 | 36.40 | 4.93 |
| 1978 | 30.58 | 4.03 |
| 1979 | 25.47 | 3.31 |
| 1980 | 21.83 | 2.65 |
| 1981 | 17.87 | 2.22 |
| 1982 | 14.81 | 1.80 |
| 1983 | 12.60 | 1.50 |
| 1984 | 10.61 | 1.26 |
| 1985 | 8.86 | 1.05 |
| 1986 | 8.83 | 1.05 |
| 1987-2000 | 8.83 | 1.05 |

All factors in grams per mile (gm/mi).

TABLE 13

EMISSION FACTORS FOR VEHICLES USING CITY STREETS (EPA) - 15% HDV MIX

| Year | CO | HC |
|---|---|---|
| 1972 | 73.06 | 11.90 |
| 1973 | 67.60 | 10.17 |
| 1974 | 62.82 | 9.17 |
| 1975 | 53.47 | 7.78 |
| 1976 | 45.65 | 6.55 |
| 1977 | 39.10 | 5.52 |
| 1978 | 33.22 | 4.59 |
| 1979 | 28.05 | 3.82 |
| 1980 | 23.48 | 3.13 |
| 1981 | 20.05 | 2.61 |
| 1982 | 16.71 | 2.10 |
| 1983 | 14.40 | 1.74 |
| 1984 | 12.38 | 1.47 |
| 1985 | 10.58 | 1.23 |
| 1986 | 10.55 | 1.23 |
| 1987-2000 | 10.55 | 1.23 |

All factors in grams per mile (gm/mi).

TABLE 14

EMISSION FACTORS FOR VEHICLES USING CITY STREETS (EPA) - 20% HDV MIX

| Year | CO | HC |
|---|---|---|
| 1972 | 75.68 | 12.60 |
| 1973 | 70.19 | 10.89 |
| 1974 | 65.36 | 9.87 |
| 1975 | 56.13 | 8.45 |
| 1976 | 48.37 | 7.19 |
| 1977 | 41.80 | 6.12 |
| 1978 | 35.88 | 5.13 |
| 1979 | 30.61 | 4.33 |
| 1980 | 25.95 | 3.60 |
| 1981 | 22.25 | 3.00 |
| 1982 | 18.61 | 2.40 |
| 1983 | 16.20 | 1.98 |
| 1984 | 14.15 | 1.69 |
| 1985 | 12.31 | 1.41 |
| 1986 | 12.28 | 1.41 |
| 1987 | 12.28 | 1.41 |

All factors in grams per mile (gm/mi).

Figure 1

CARBON MONOXIDE EMISSIONS VS AVERAGE ROUTE SPEED
FOR UNCONTROLLED VEHICLES-PRE 1966 MODELS
(ROSE'S WORK)

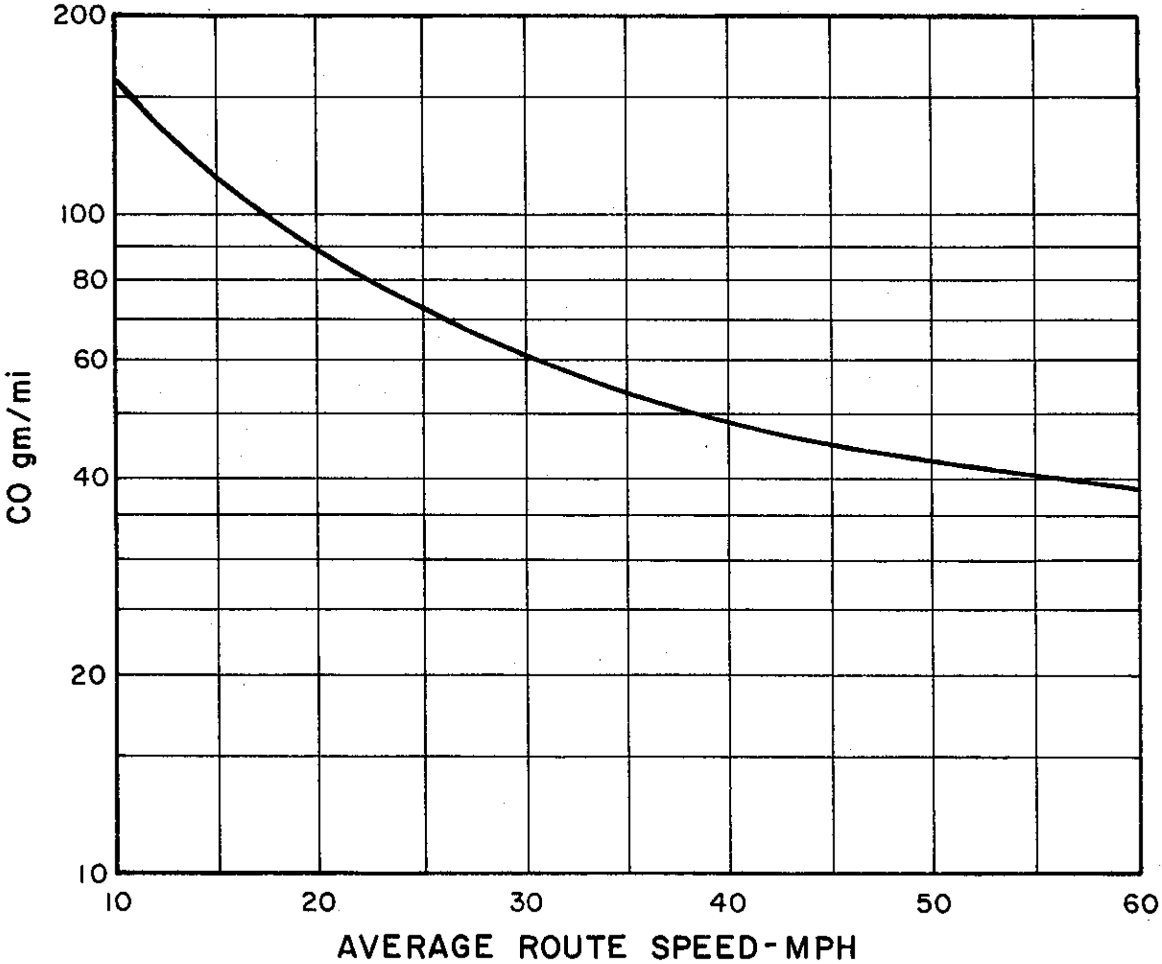


Figure 2

## EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON FREEWAYS 5% HDV

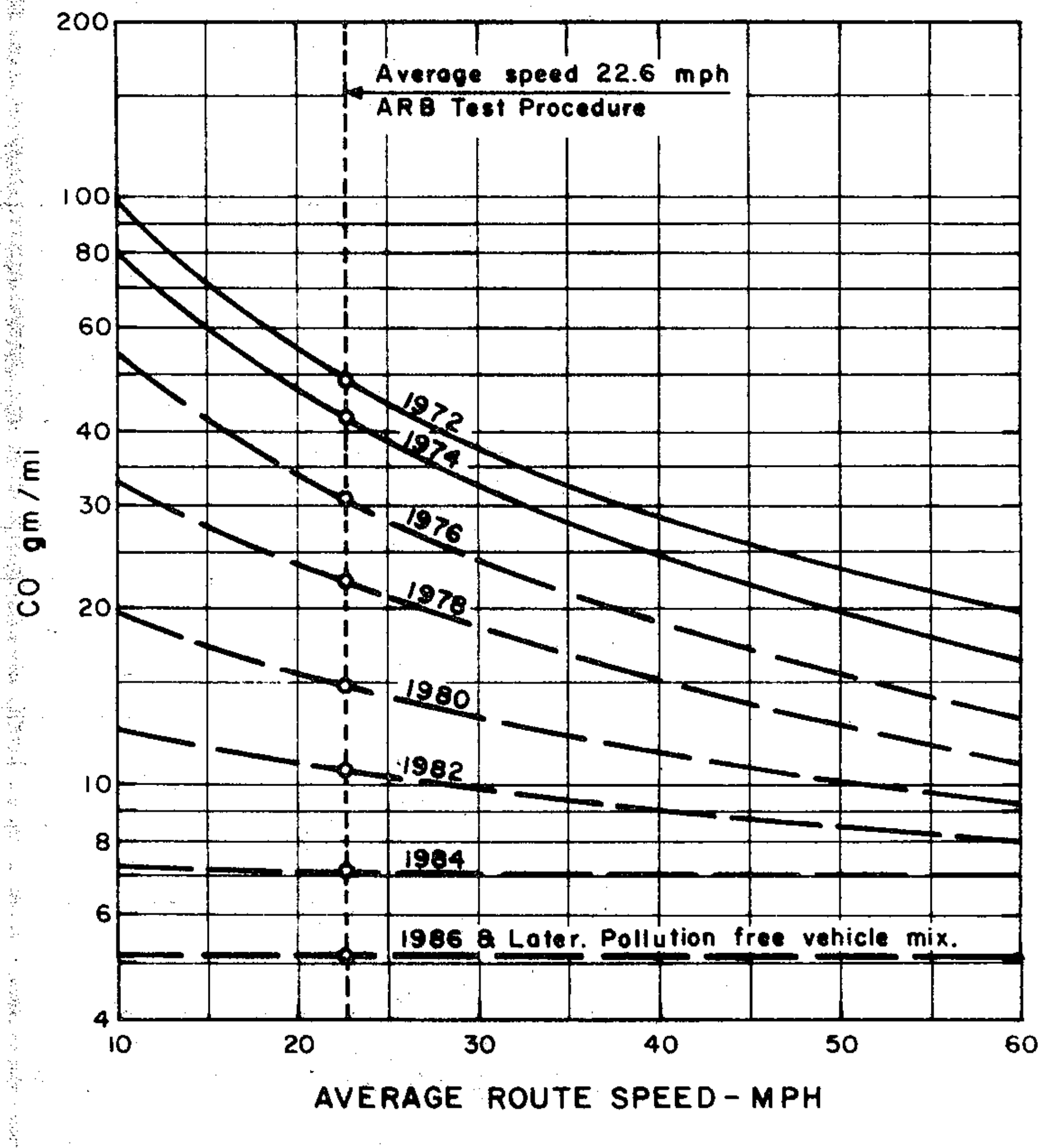


Figure 3

# EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON FREEWAYS 10% HDV

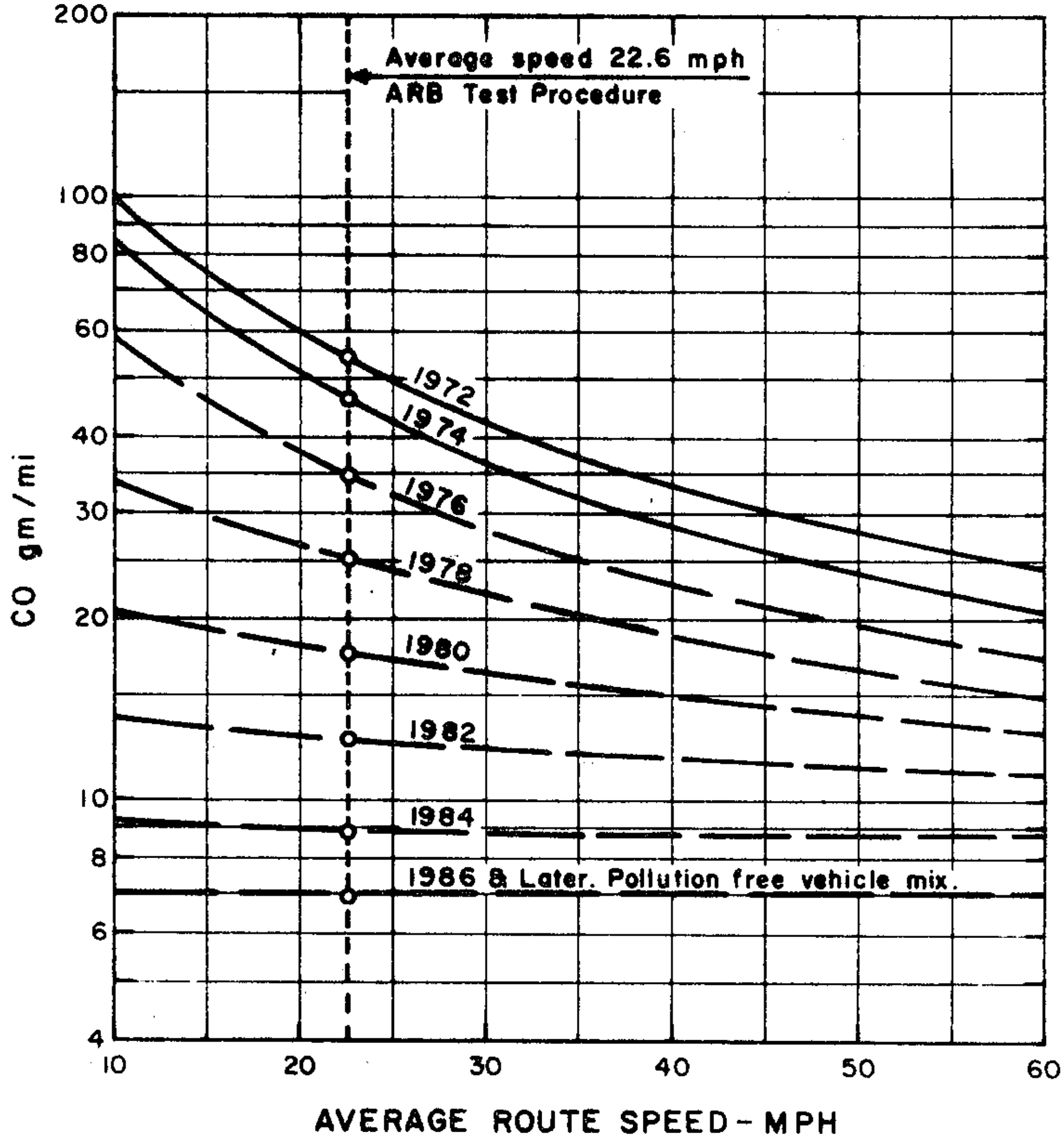


Figure 4

EMISSION FACTORS FOR CARBON MONOXIDE
VS AVERAGE ROUTE SPEED
ON FREEWAYS
15% HDV

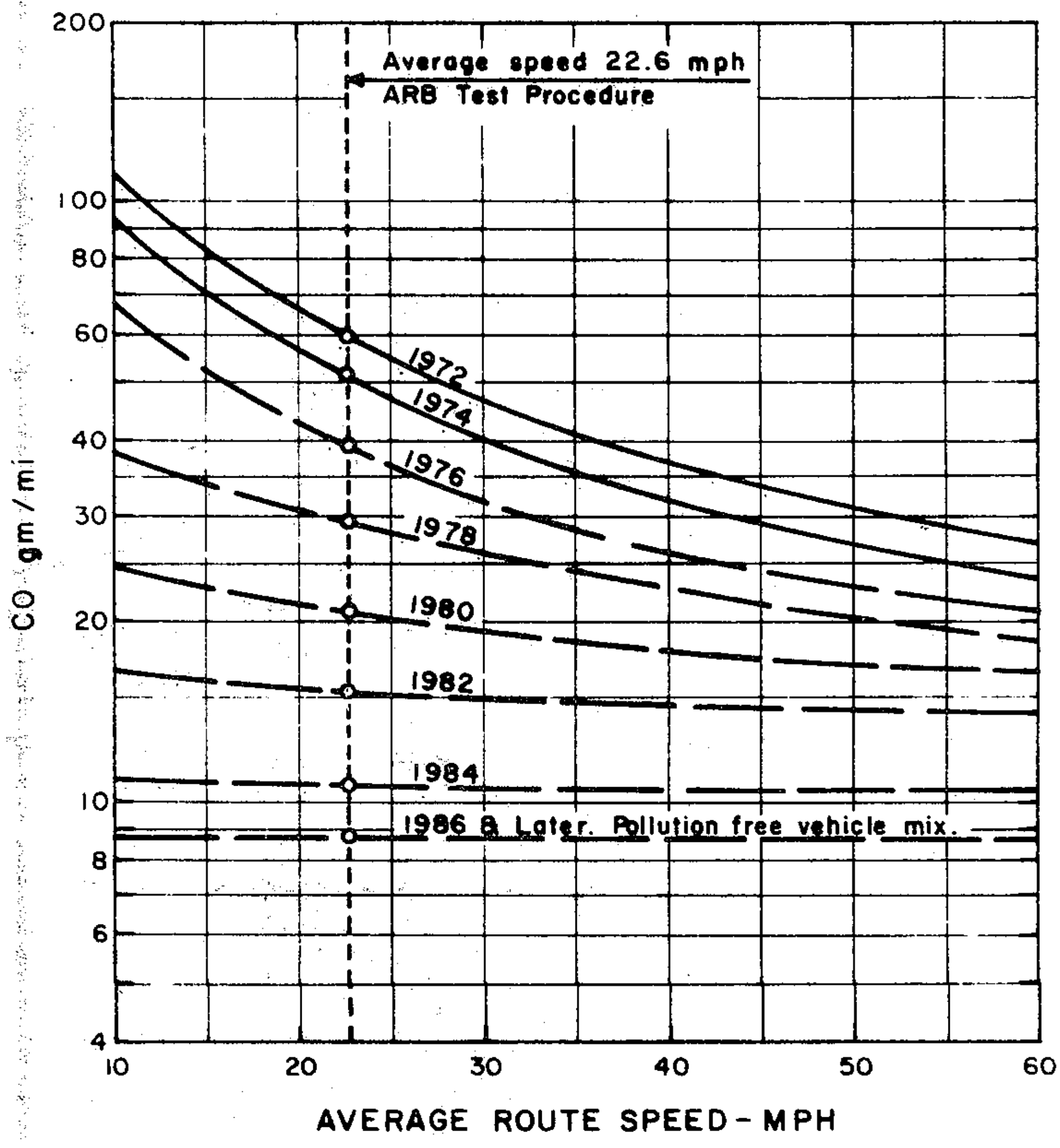


Figure 5

## EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON FREEWAYS 20% HDV

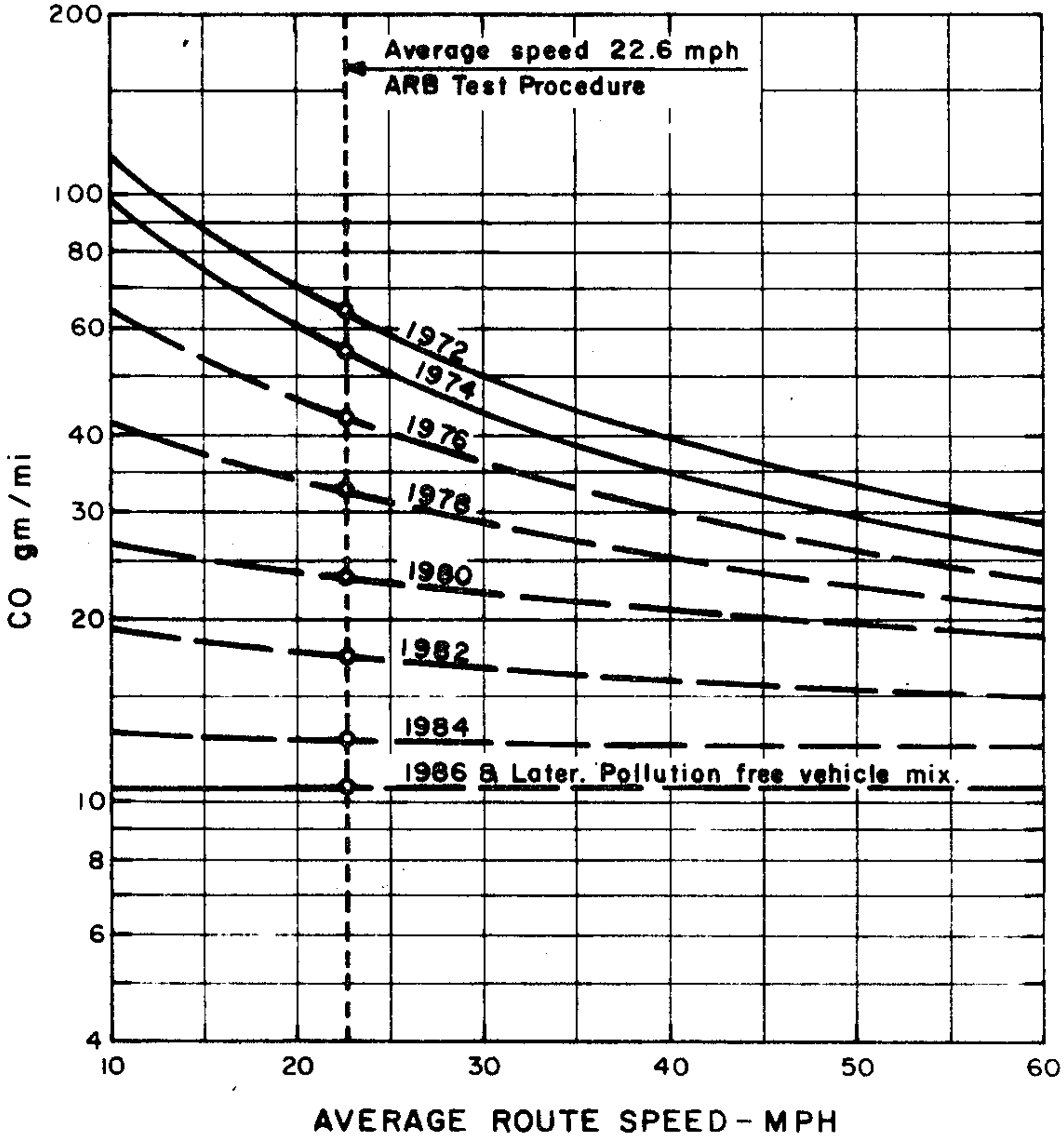


Figure 6

# EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON CITY STREETS

## 5% HDV

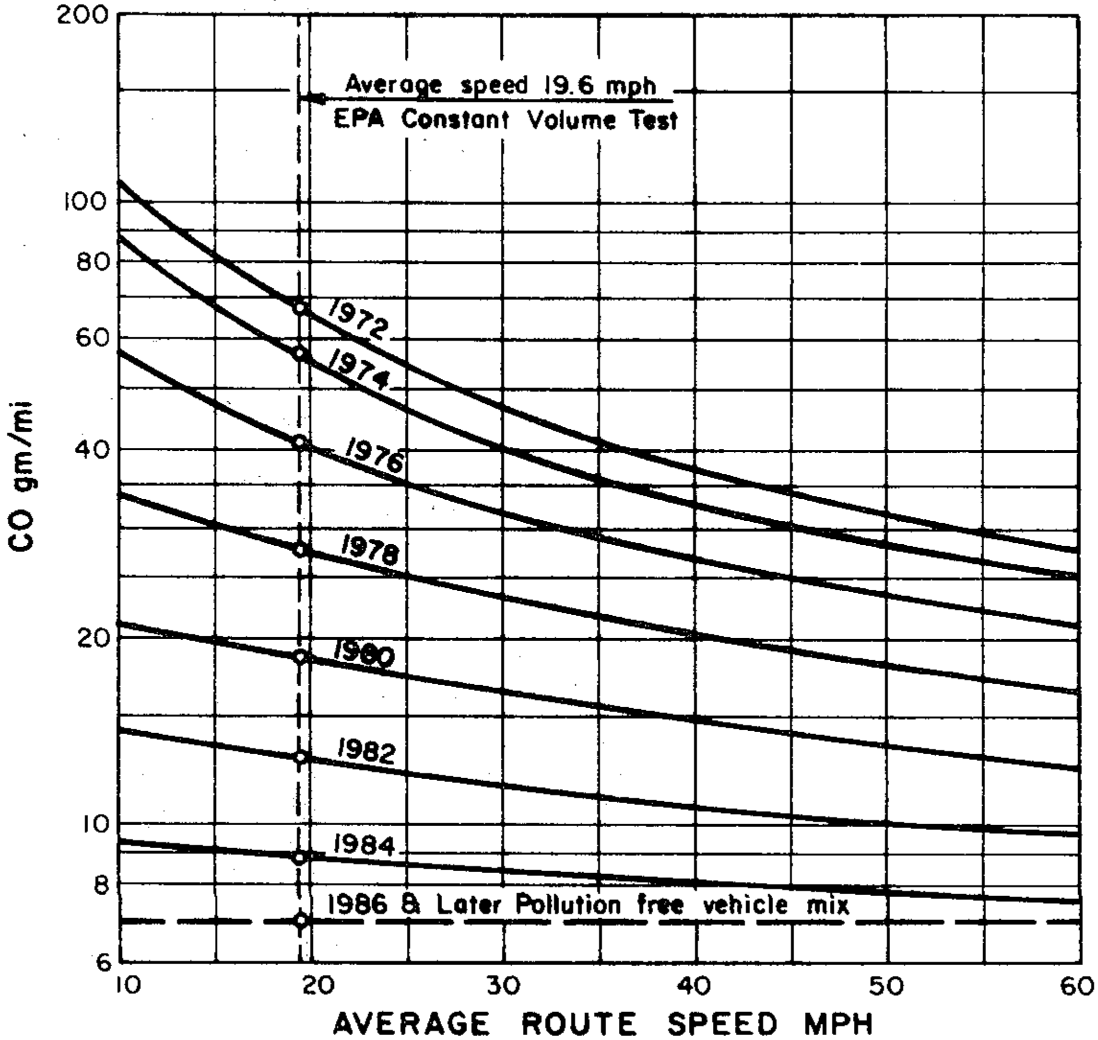


Figure 7

# EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON CITY STREETS 10 % HDV

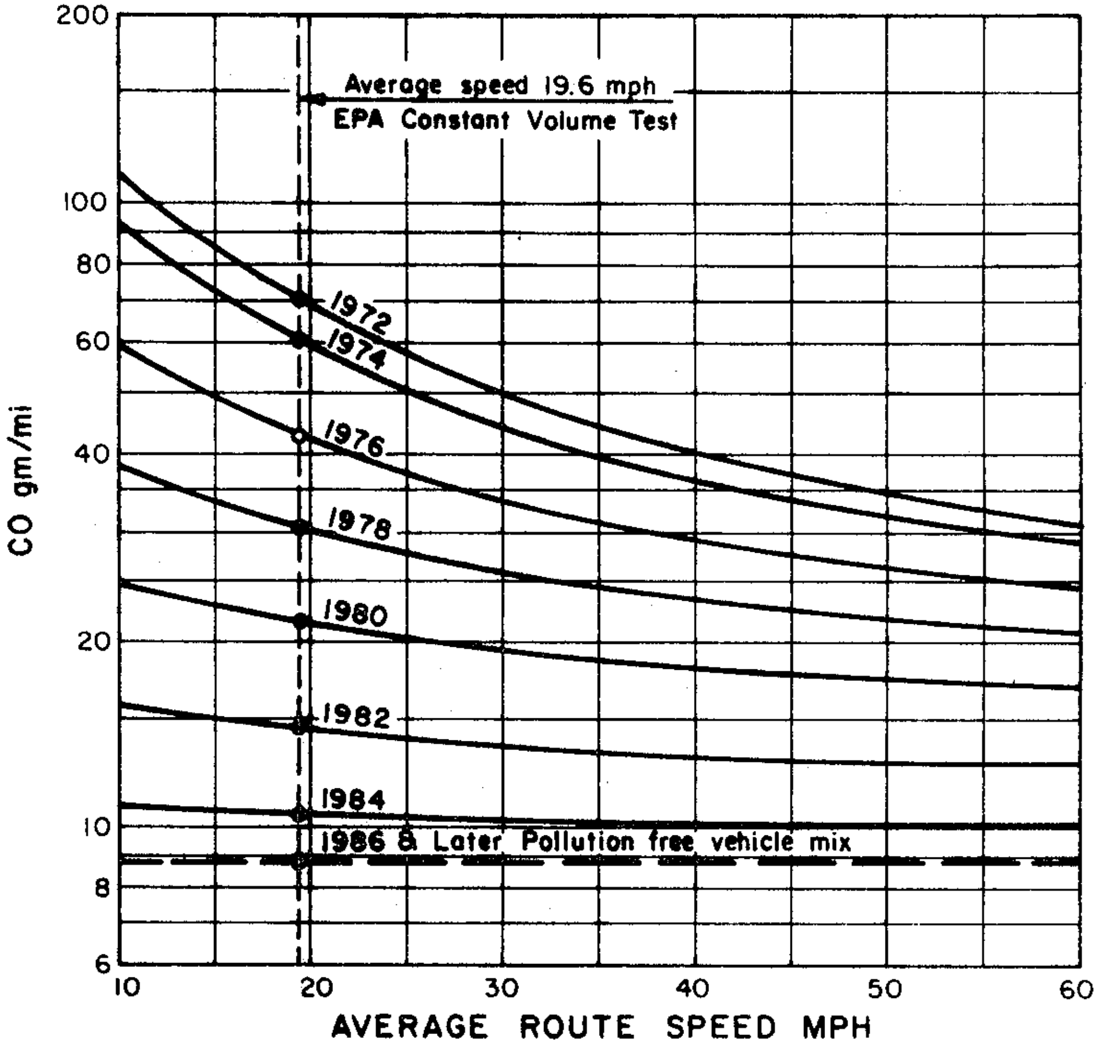


Figure 8

# EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON CITY STREETS 15% HDV

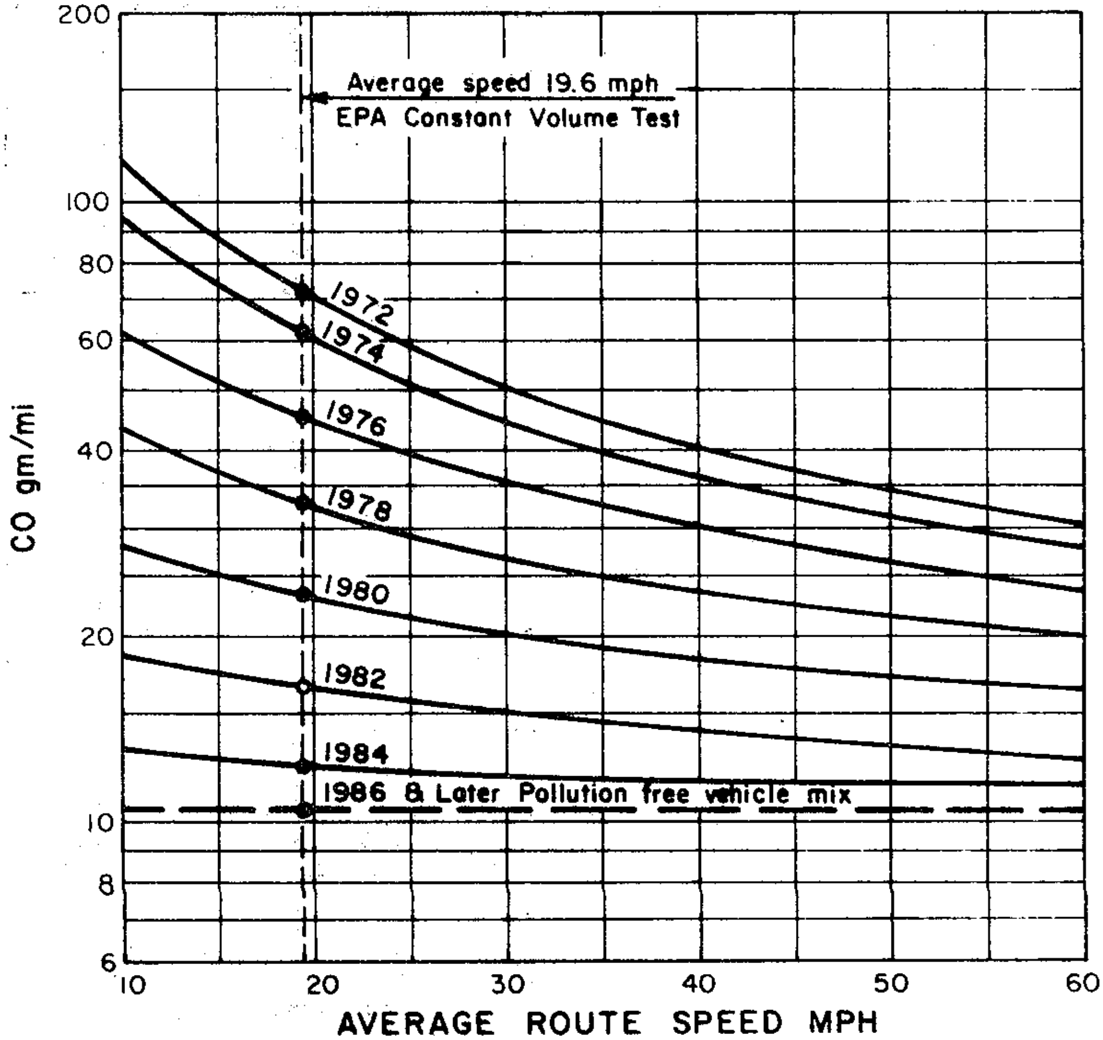


Figure 9

## EMISSION FACTORS FOR CARBON MONOXIDE VS AVERAGE ROUTE SPEED ON CITY STREETS 20% HDV

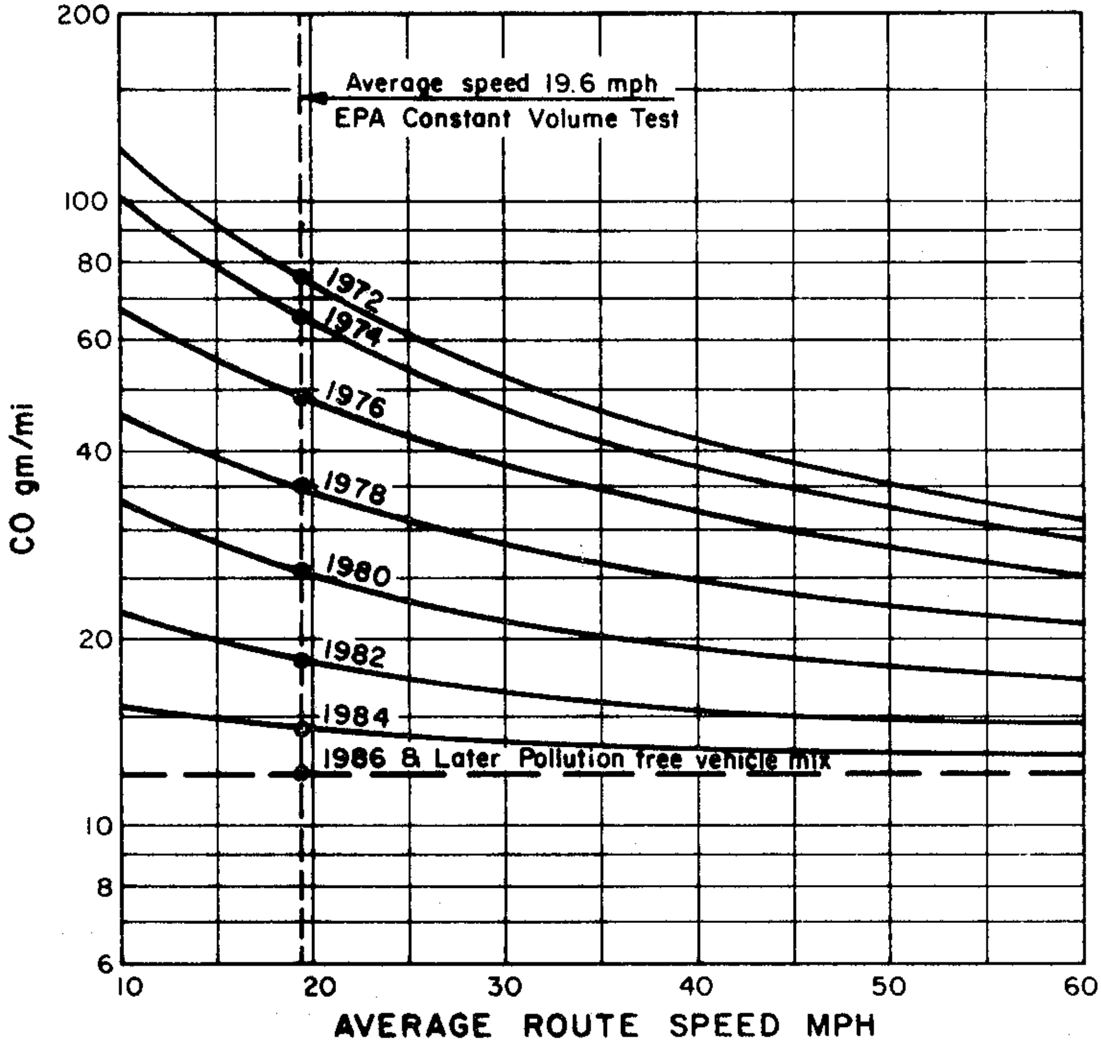


Figure 10

HYDROCARBON EMISSIONS VS AVERAGE ROUTE SPEED FOR UNCONTROLLED VEHICLES – PRE 1966 MODELS (ROSE'S WORK)

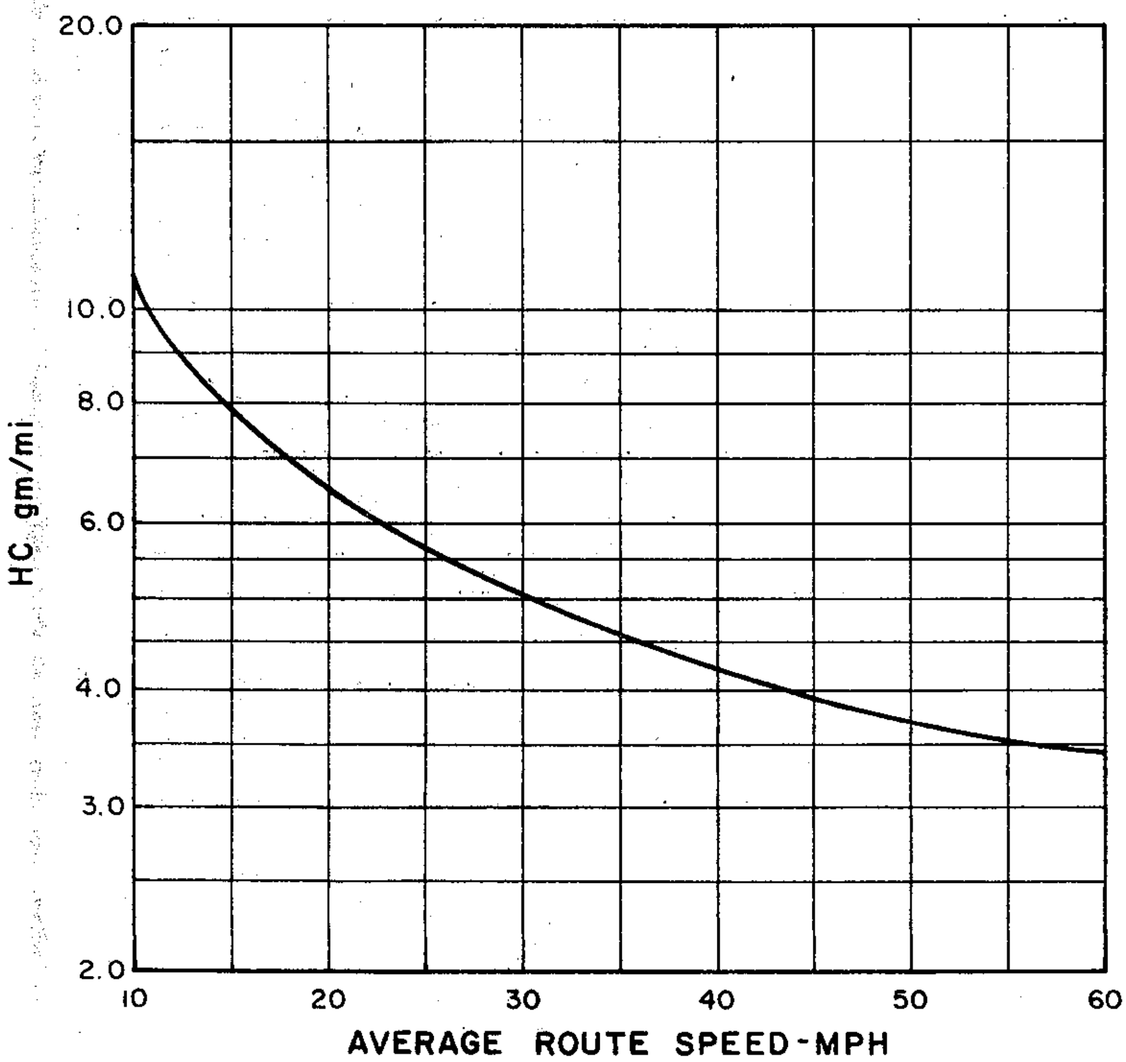


Figure II

## EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON FREEWAYS
## 5% HDV

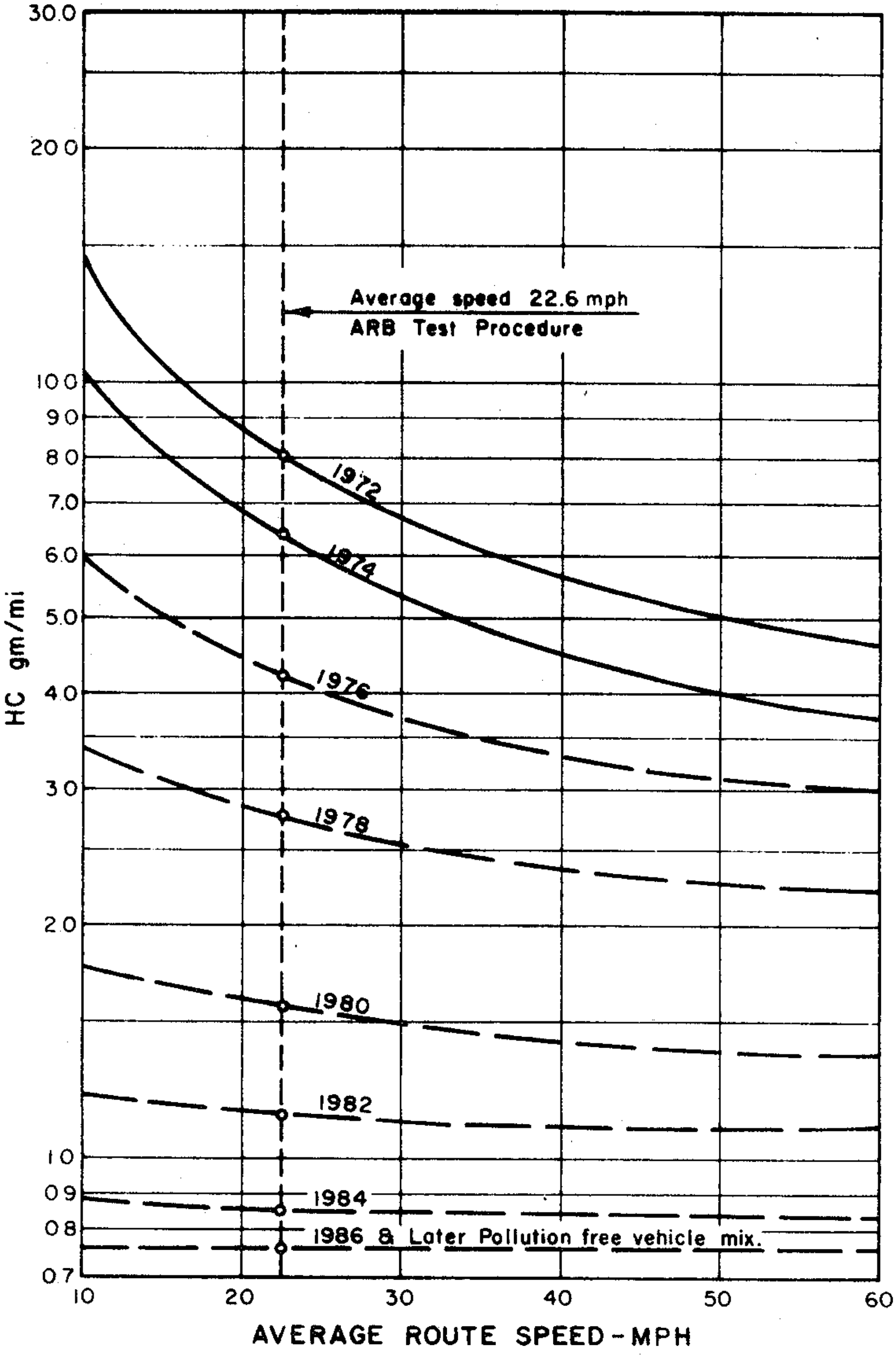


Figure 12

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON FREEWAYS 10 % HDV

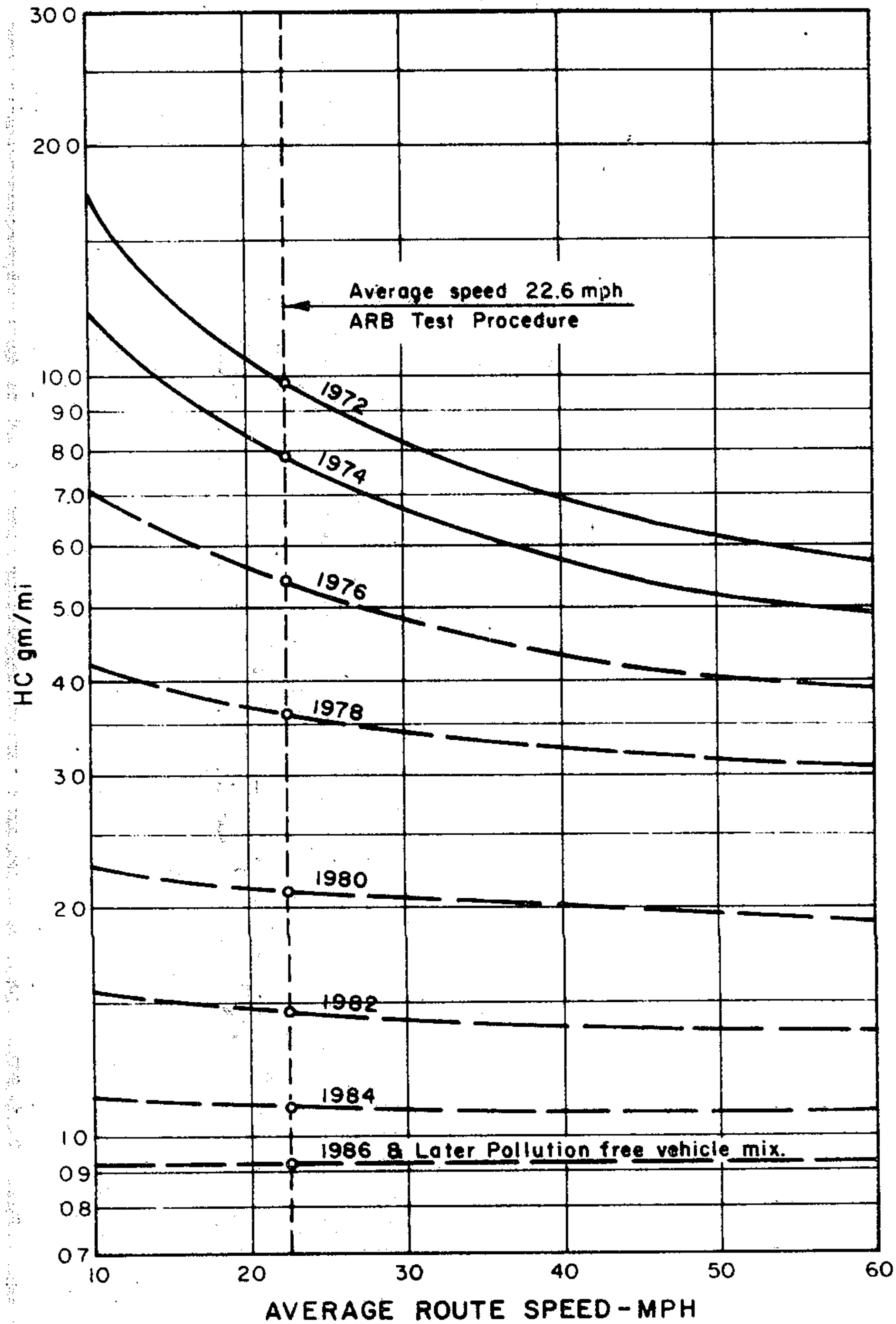


Figure 13

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON FREEWAYS 15% HDV

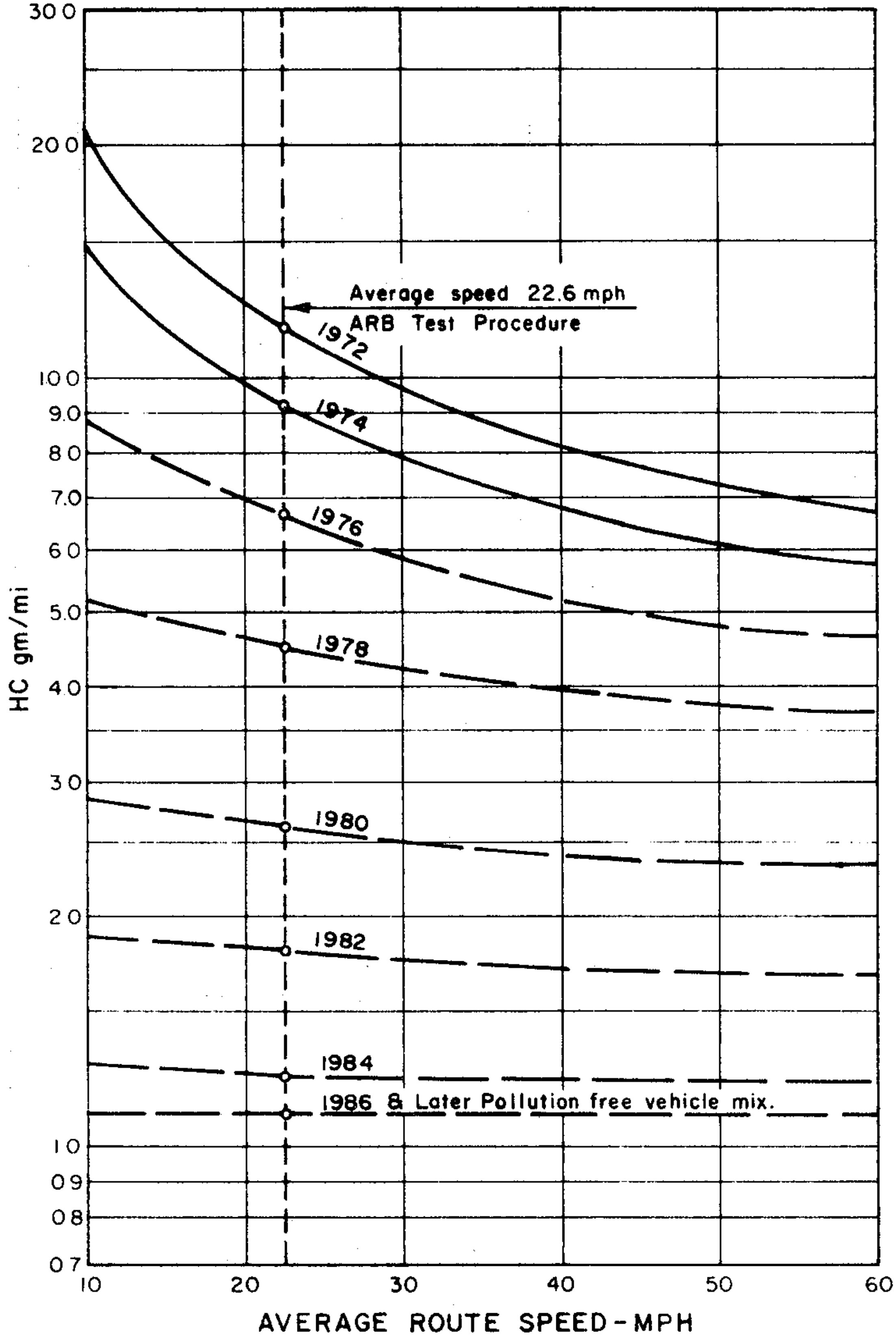


Figure 14

# EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON FREEWAYS 20% HDV

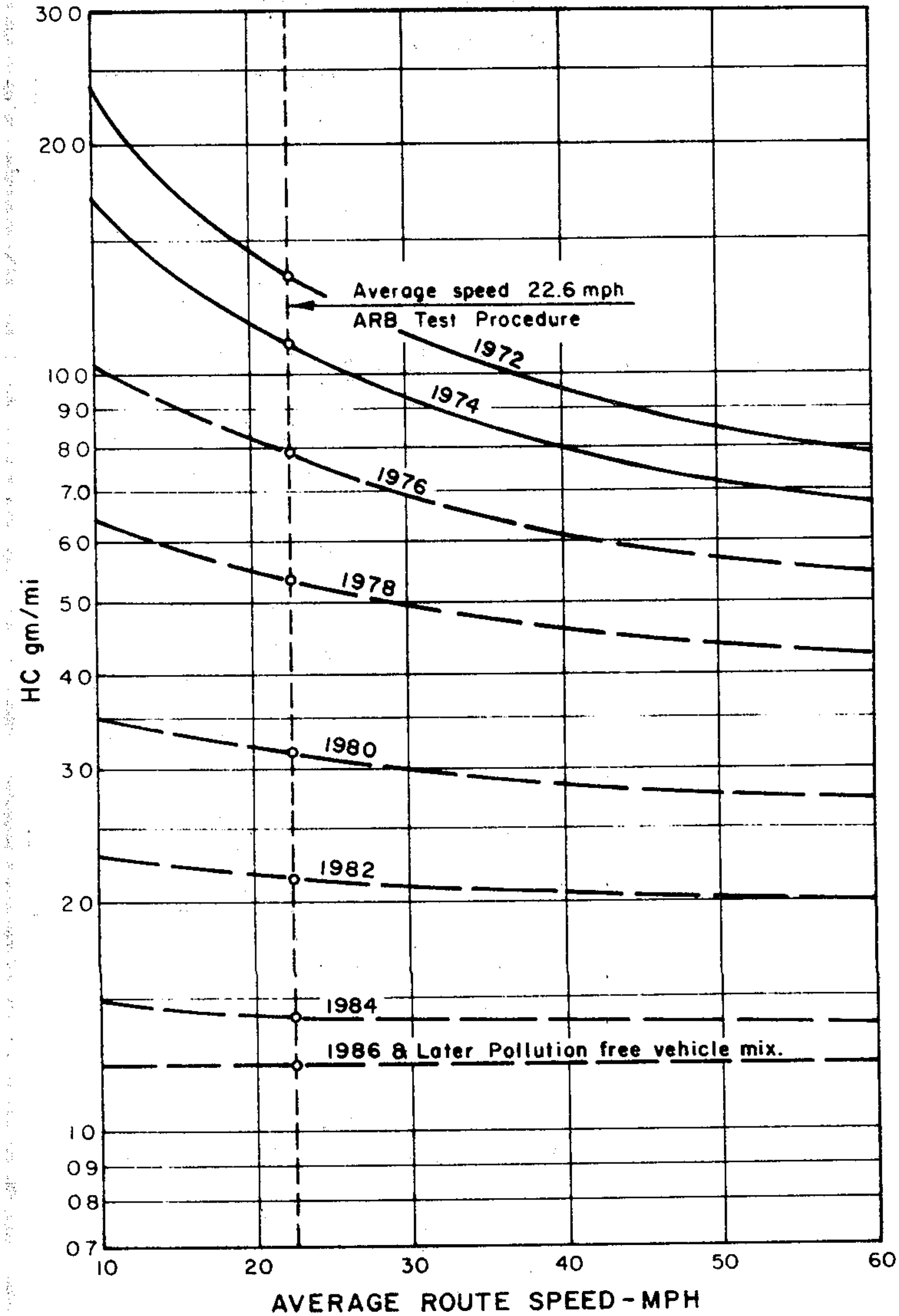


Figure 15

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON CITY STREETS
5 % HDV

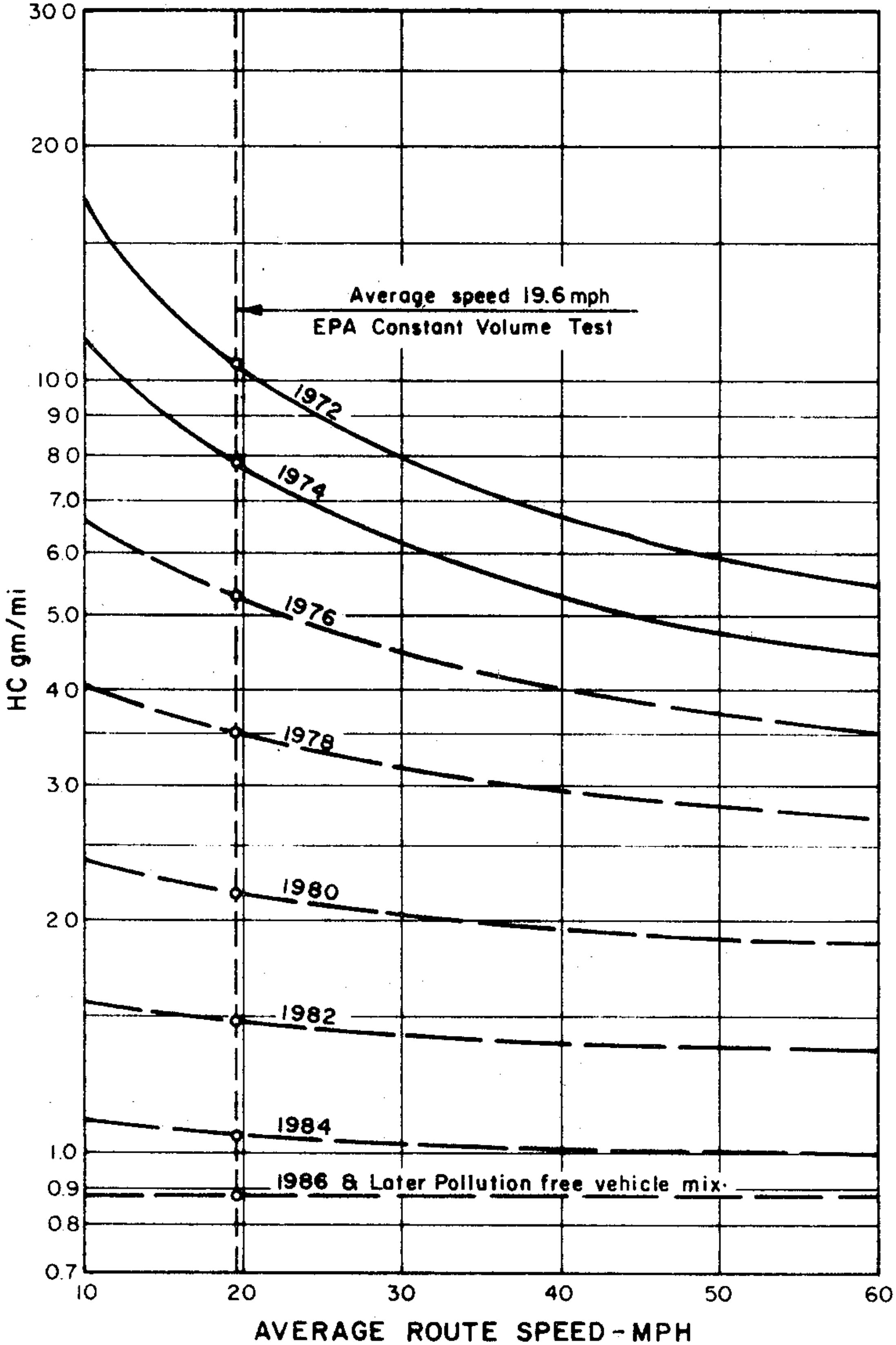


Figure 16

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON CITY STREETS
10 % HDV

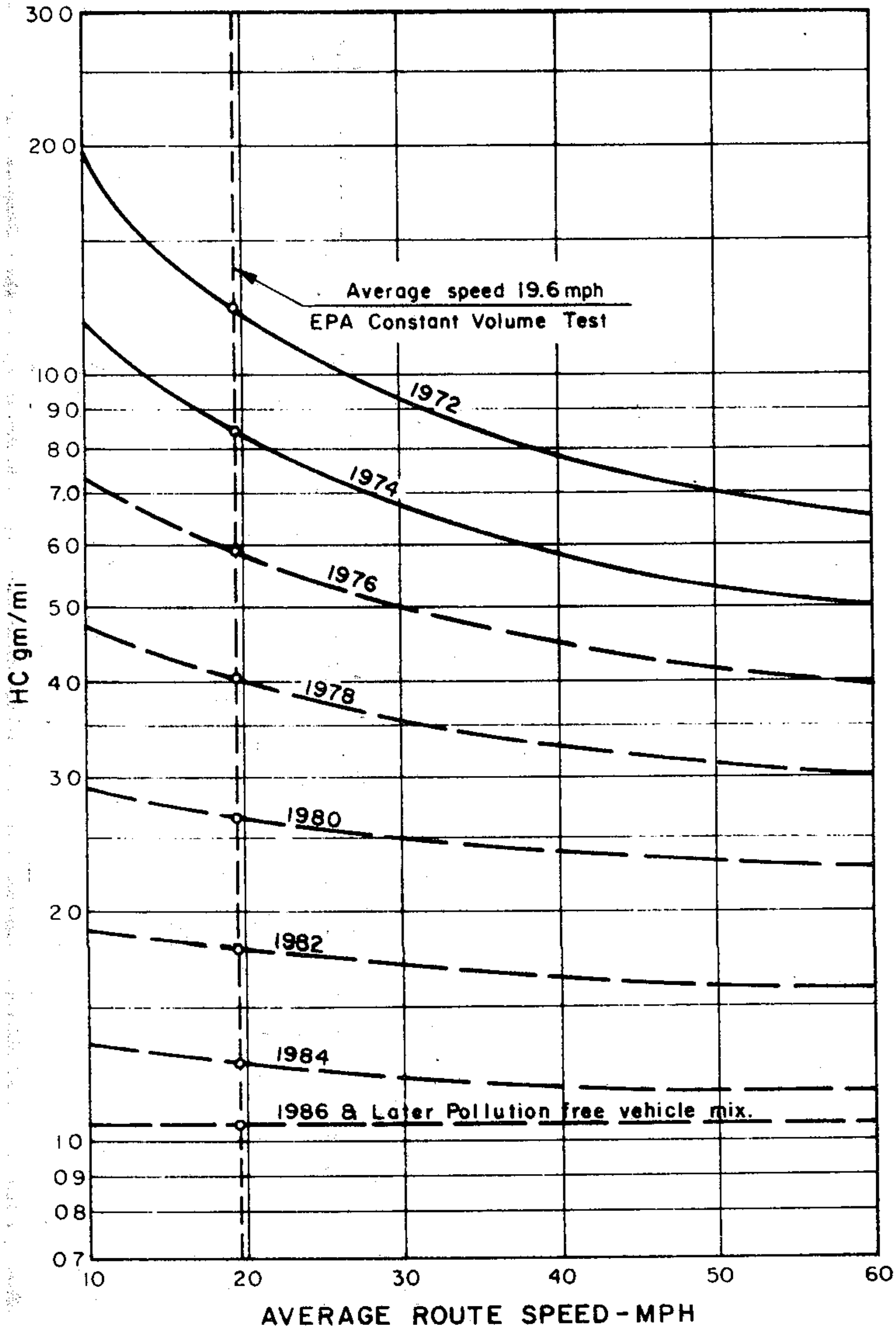


Figure 17

## EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON CITY STREETS 15 % HDV

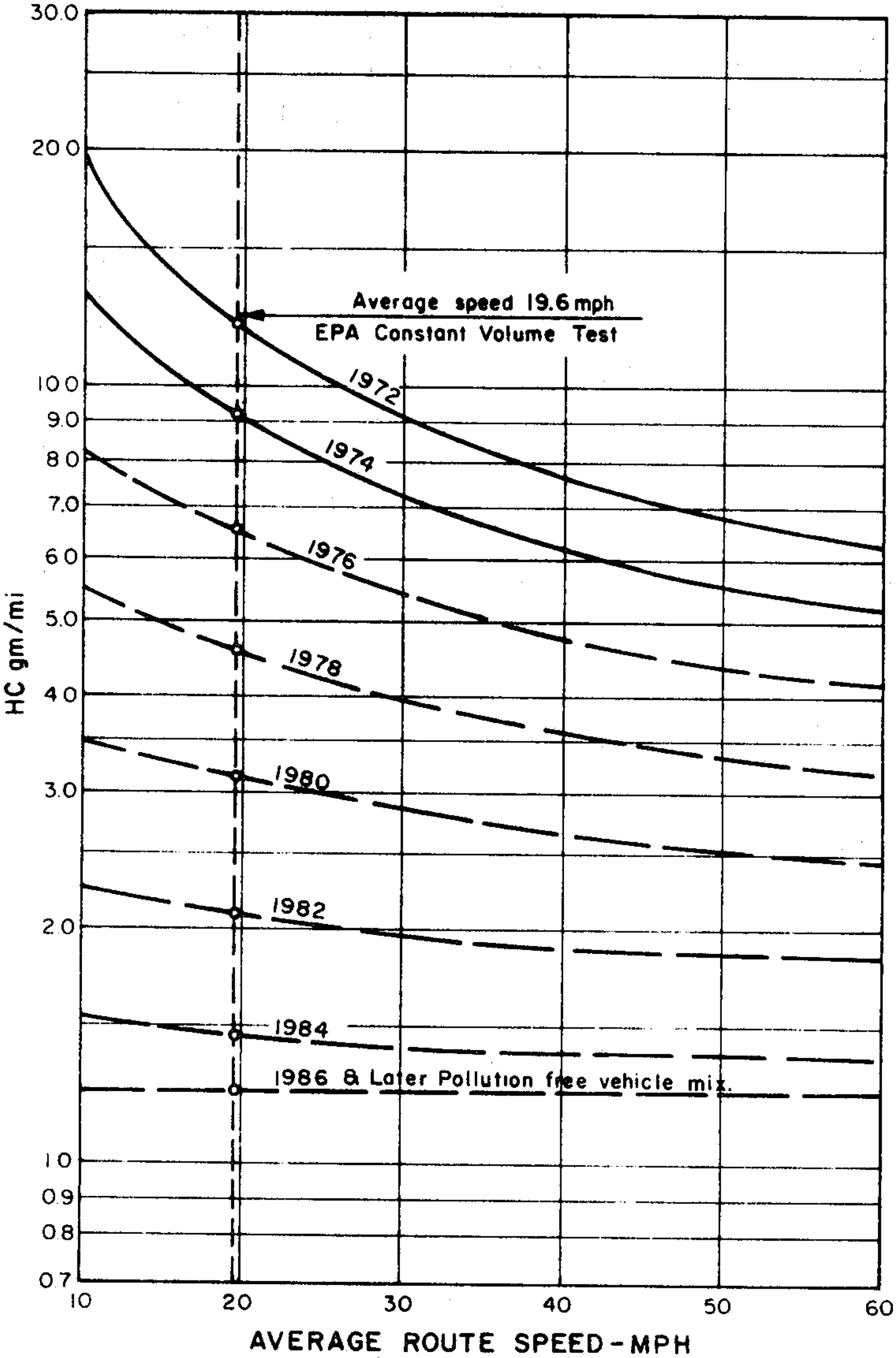
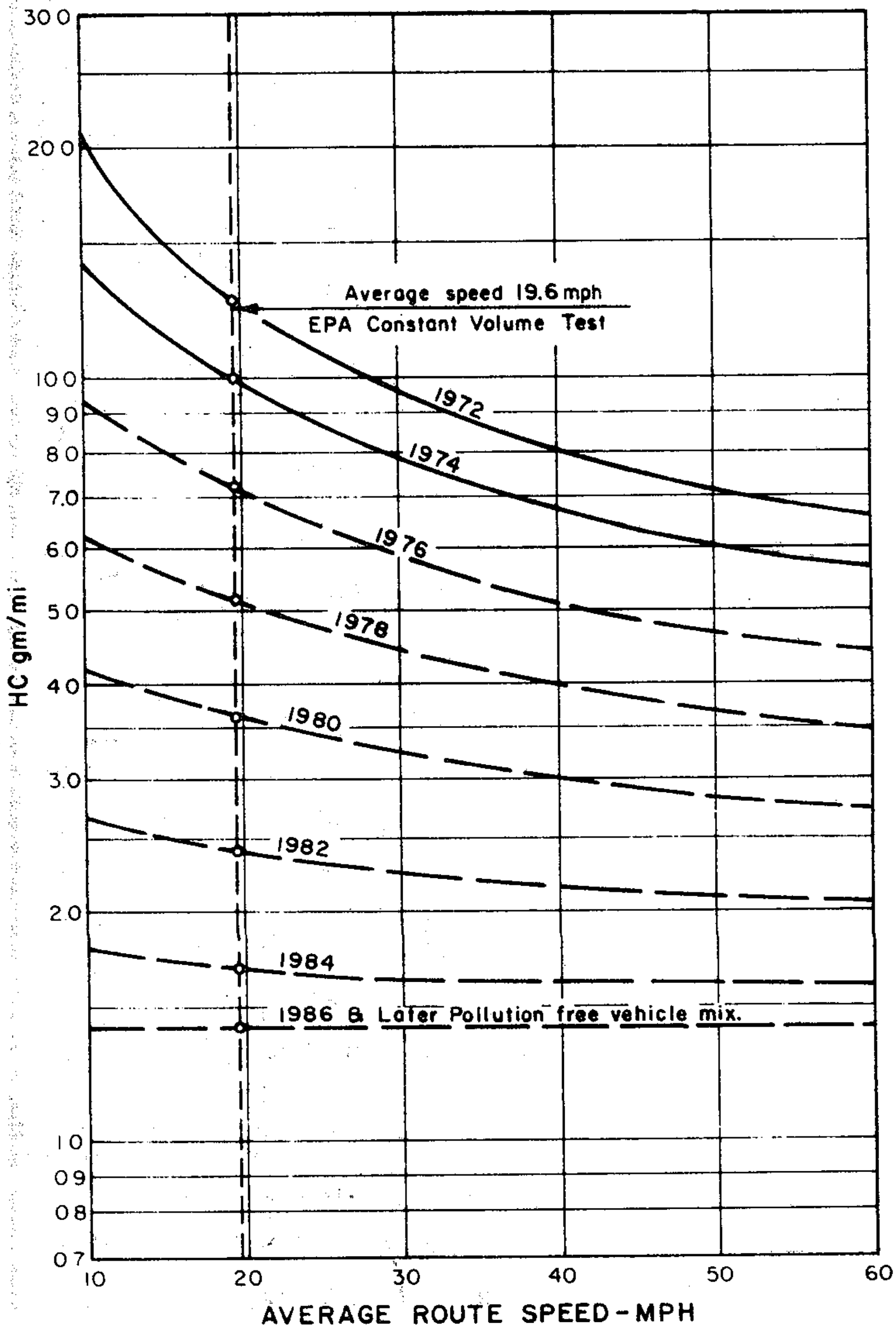


Figure 18

EMISSION FACTORS FOR HYDROCARBONS VS AVERAGE ROUTE SPEEDS ON CITY STREETS 20 % HDV



# APPENDIX A

## SAMPLE CALCULATION OF ARB EMISSION FACTORS FOR 1972

The following tables summarize the calculations made of ARB Emission Factors for the calendar year 1972. Additional data for later years may be obtained upon request to the Division of Highways, Materials and Research Department in Sacramento.

# APPENDIX A

## SAMPLE CALCULATIONS OF ARB EMISSION FACTORS FOR 1972

CO:

| | Light Duty Vehicles | | | | | | Heavy Duty Vehicles | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | ARB Emission Standards (Table 1) | Mileage (Table 4) | Deterior. Factor (Table 2) | Standard x Deterior. | % Frac. of Miles Traveled (Table 4) | Fraction x Standard x Deterior. Factor | ARB Emission Standards (Table 1) | Mileage (Table 5) | Deterior. Factor (Table 3) | Standard x Deterior. | % Frac. of Miles Traveled (Table 5) | Fraction x Standard x Deterior. Factor |
| 72 | 23 | 15,000 | 1.15 | 26.45 | 17.4 | 4.60 | 80 | 14,000 | 1.15 | 92.0 | 9.09 | 8.36 |
| 71 | 23 | 28,000 | 1.23 | 28.29 | 15.0 | 4.24 | 80 | 28,000 | 1.23 | 98.4 | | 8.93 |
| 70 | 23 | 39,000 | 1.28 | 29.44 | 12.7 | 3.74 | 80 | 42,000 | 1.29 | 103.3 | | 9.40 |
| 69 | 34 | 48,600 | 1.31 | 44.54 | 11.1 | 4.94 | 165 | 56,000 | 1.0 | 165 | | 15.0 |
| 68 | 34 | 57,000 | 1.35 | 45.90 | 9.7 | 4.45 | | 70,000 | | | | |
| 67 | 34 | 64,000 | 1.25 | 42.50 | 8.1 | 3.44 | | 84,000 | | | | |
| 66 | 34 | 69,300 | 1.27 | 43.18 | 6.1 | 2.63 | | 98,000 | | | | |
| 65 | 80 | 74,300 | 1.00 | 80.00 | 5.8 | 4.64 | | 112,000 | | | | |
| 64 | 80 | 78,700 | 1.00 | 80.00 | 5.1 | 4.08 | | 126,000 | | | | |
| 63 | 80 | 82,900 | 1.00 | 80.00 | 4.9 | 3.92 | | 140,000 | | | | |
| 62 | 80 | 86,400 | 1.00 | 80.00 | 4.1 | 3.28 | 165 | 154,000 | 1.0 | 165 | 9.09 | 15.0 |

Total = 43.9 gm/mi

Total = 146.7 gm/mi

Assume 5% HDV Mix   perage

Overall total = 0.95(43.9) + 0.050(146.7) = 49.11 gm/mi

HC:

| YEAR | Light Duty Vehicles: ARB Emission Standards (Table 1) | Mileage (Table 4) | Deterior. Factor (Table 2) | Standard x Deterior. | % Frac. of Miles Traveled (Table 4) | Fraction x Standard x Deterior. Factor | Heavy Duty Vehicles: ARB Emission Standards (Table 1) | Mileage (Table 5) | Deterior. Factor (Table 3) | Standard x Deterior. | % Frac. of Miles Traveled (Table 5) | Fraction x Standard x Deterior. Factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72 | 1.5 | 15,000 | 1.10 | 1.65 | 17.4 | .287 | 18.1 | 14,000 | 1.10 | 19.9 | 9.09 | 1.81 |
| 71 | 2.2 | 28,000 | 1.16 | 2.56 | 15.0 | .383 | 18.1 | 28,000 | 1.16 | 21.0 | | 1.91 |
| 70 | 2.2 | 39,000 | 1.19 | 2.62 | 12.7 | .333 | 18.1 | 42,000 | 1.19 | 21.5 | | 1.96 |
| 69 | 6.5 | 57,000 | 1.21 | 7.87 | 11.1 | .873 | 49.2 | 56,000 | 1.0 | 49.2 | | 4.47 |
| 68 | 6.5 | 57,000 | 1.24 | 8.06 | 9.7 | .782 | 49.2 | 70,000 | | 49.2 | | 4.47 |
| 67 | 6.5 | 64,000 | 1.34 | 8.71 | 8.1 | .706 | 52.2 | 84,000 | | 52.2 | | 4.74 |
| 66 | 6.5 | 69,300 | 1.36 | 8.84 | 6.1 | .539 | | 98,000 | | | | |
| 65 | 14.0 | 74,300 | 1.0 | 14.0 | 5.8 | .812 | | 112,000 | | | | |
| 64 | 14.0 | 78,700 | 1.0 | | 5.1 | .714 | | 126,000 | | | | |
| 63 | 14.0 | 82,900 | 1.0 | | 4.9 | .686 | | 140,000 | | | | |
| 62 | 14.0 | 86,400 | 1.0 | 14.0 | 4.1 | .574 | 52.2 | 154,000 | 1.0 | 52.2 | 9.09 | 4.74 |
| | | | | | | Total = 6.12 gm/mi | | | | | | Total = 43.06 gm/mi |

Assume 5% HDV Mix

Overall total = 0.95(6.12) + 0.05(43.06)= 7.98 gm/mi

## APPENDIX B

## SAMPLE CALCULATION OF EPA EMISSION FACTORS FOR 1972

The following tables summarize the calculations made of EPA Emission Factors for the calendar year 1972. Additional data for later years may be obtained upon request to the Division of Highways, Materials and Research Department in Sacramento.

APPENDIX B

SAMPLE CALCULATIONS OF EPA EMISSION FACTORS FOR 1972

CO:

| | Light Duty Vehicles | | | | | | Heavy Duty Vehicles | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | EPA Emission Standards (Table 10) | Mileage (Table 4) | Deterior. Factor (Table 2) | Standard x Deterior. | % Frac. of Miles Traveled (Table 4) | Fraction x Standard x Deterior. Factor | EPA Emission Standards (Table 10) | Mileage (Table 5) | Deterior. Factor (Table 2) | Standard x Deterior. | % Frac. of Miles Traveled (Table 5) | Fraction x Standard x Deterior. Factor |
| 72 | 31 | 15,000 | 1.15 | 35.7 | 17.4 | 6.20 | 53 | 14,000 | 1.15 | 60.95 | 9.09 | 5.54 |
| 71 | 35 | 28,000 | 1.23 | 43.1 | 15.0 | 6.46 | 80 | 28,000 | 1.23 | 98.4 | | 8.94 |
| 70 | 35 | 39,000 | 1.28 | 44.8 | 12.7 | 5.69 | 80 | 42,000 | 1.29 | 103.2 | | 9.38 |
| 69 | 50 | 48,600 | 1.31 | 65.5 | 11.1 | 7.27 | 129 | 56,000 | 1.0 | 129 | | 11.73 |
| 68 | 50 | 57,000 | 1.35 | 67.5 | 9.7 | 6.55 | | 70,000 | | | | |
| 67 | 62 | 64,000 | 1.25 | 77.5 | 8.1 | 6.28 | | 84,000 | | | | |
| 66 | 62 | 69,300 | 1.27 | 78.7 | 6.1 | 4.80 | | 98,000 | | | | |
| 65 | 110 | 74,300 | 1.00 | 110 | 5.8 | 6.38 | | 112,000 | | | | |
| 64 | | 78,700 | | | 5.1 | 5.61 | | 126,000 | | | | |
| 63 | | 82,900 | | | 4.9 | 5.39 | | 140,000 | | | | |
| 62 | 110 | 86,400 | 1.00 | 110 | 4.1 | 4.51 | 129 | 154,000 | 1.0 | 129 | 9.09 | 11.73 |

Total = 65.14 gm/mi

Total = 117.70 gm/mi

Assume 5% HDV Mix

Overall total = 0.95(65.14) + 0.05(117.70) = 67.80 gm/mi

HC:

| YEAR | Light Duty Vehicles: EPA Emission Standards (Table 10) | Mileage (Table 4) | Deterior. Factor (Table 2) | Standard x Deterior. | % Frac. of Miles Traveled (Table 4) | Fraction x Standard x Deterior. Factor | Heavy Duty Vehicles: EPA Emission Standards (Table 10) | Mileage (Table 5) | Deterior. Factor (Table 2) | Standard x Deterior. | % Frac. of Miles Traveled (Table 5) | Fraction x Standard x Deterior Factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 72 | 3.26 | 15,000 | 1.10 | 3.59 | 17.4 | .624 | 12.9 | 14,000 | 1.10 | 14.19 | 9.09 | 1.29 |
| 71 | 3.99 | 28,000 | 1.16 | 4.63 | 15.0 | .694 | 18.1 | 28,000 | 1.16 | 21.0 | | 1.91 |
| 70 | 3.99 | 39,000 | 1.19 | 4.75 | 12.7 | .603 | 18.1 | 42,000 | 1.19 | 21.5 | | 1.96 |
| 69 | 8.6 | 48,600 | 1.21 | 10.4 | 11.1 | 1.16 | 21.7 | 56,000 | 1.0 | 21.7 | | 1.97 |
| 68 | 8.6 | 57,000 | 1.24 | 10.7 | 9.7 | 1.03 | 21.7 | 70,000 | | 21.7 | | 1.97 |
| 67 | 8.9 | 64,000 | 1.34 | 11.9 | 8.1 | .966 | 26.9 | 84,000 | | 26.9 | | 2.45 |
| 66 | 8.9 | 69,300 | 1.36 | 12.1 | 6.1 | .738 | | 98,000 | | | | |
| 65 | 16.1 | 74,300 | 1.0 | 16.1 | 5.8 | .934 | | 112,000 | | | | |
| 64 | 16.1 | 78,700 | 1.0 | 16.1 | 5.1 | .821 | | 126,000 | | | | |
| 63 | 16.9 | 82,900 | 1.0 | 16.9 | 4.9 | .829 | | 140,000 | | | | |
| 62 | 16.9 | 86,400 | 1.0 | 16.9 | 4.1 | .694 | 26.9 | 154,000 | 1.0 | 26.9 | 9.09 | 2.45 |
| | | | | | | Total = 9.79 gm/mi | | | | | | Total = 23.80 gm/mi |

Assume 5% HDV Mix

Overall total = 0.95(9.79) + 0.05(23.80) = 10.49 gm/mi